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Original Communications

SPATIAL VECTORCARDIOGRAPHY: TECHNIQUE FOR THE SIMULTANEOUS RECORDING OF THE FRONTAL, SAGITTAL, AND HORIZONTAL PROJECTIONS. I.

Arthur Grishman, M.D., E. Raymond Borun, M.D., and Harry L. Jaffe, M.D.

New York, N. Y.

Spatial vectorcardiography is a method for the representation of the magnitude, sense, and direction of the electromotive field forces generated during cardiac activity. If the electrical forces produced by the activity of each muscle fiber are visualized vectorially, their integral or sum will produce the cardiac vector at the moment of observation (instantaneous integral vector). The record of all instantaneous integral vectors is termed the vectorcardiogram. Only spatial vectorcardiography allows representation of the true magnitude, sense, and direction of the electromotive field forces.

The application of rectangular coordinates for the analysis of the manifest potential difference, in contrast to Einthoven's polar coordinate system, was introduced by Williams.[1] Basing his work on the premise of Einthoven's triangle, Mann, in 1920, presented the concept of vectorcardiography.[2] By this means, the instantaneous magnitude, sense, and direction of the manifest potential difference, as projected on a plane parallel to the frontal, could be demonstrated. In 1938, he published the successful recording of the vectorcardiogram with a specially designed galvanometer.[3] Sulzer and Duchosal,[4] Schellong,[5] Wilson and Johnston,[6] and Hollmann and Hollmann[7] used a cathode ray oscilloscope for the same purpose. Spatial presentations of the cardiac vector were published by Duchosal and Sulzer,[8] Schellong,[5] Rochet and Vastesaeger,[9] and, recently, by Conway, Cronvich, and Burch.[10]

Of the numerous geometric arrangements suggested for the purpose of electrode placement in spatial vectorcardiography, two have gained widest acceptance: (1) the equilateral tetrahedron suggested by Wilson, Johnston, and Kossmann[11] and (2) the rectangular solid or "double cube" of Duchosal and Sulzer.[8]

From the Cardiographic Department and the Cardiovascular Research Group, The Mount Sinai Hospital, New York.

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In the investigations in spatial vectorcardiography conducted at The Mount Sinai Hospital since 1948, the various geometric arrangements have been analyzed. The results of simultaneous recordings of spatial vectorcardiograms in a large series of patients with normal as well as abnormal electrocardiograms have led us to adopt the geometric arrangement of a cube for the electrode placement in preference to (a) the tetrahedral arrangement, (b) a sagittal triangle, similar to that suggested by Arrighi,[12] and (c) the "double cube" arrangement of Duchosal and Sulzer.[8]

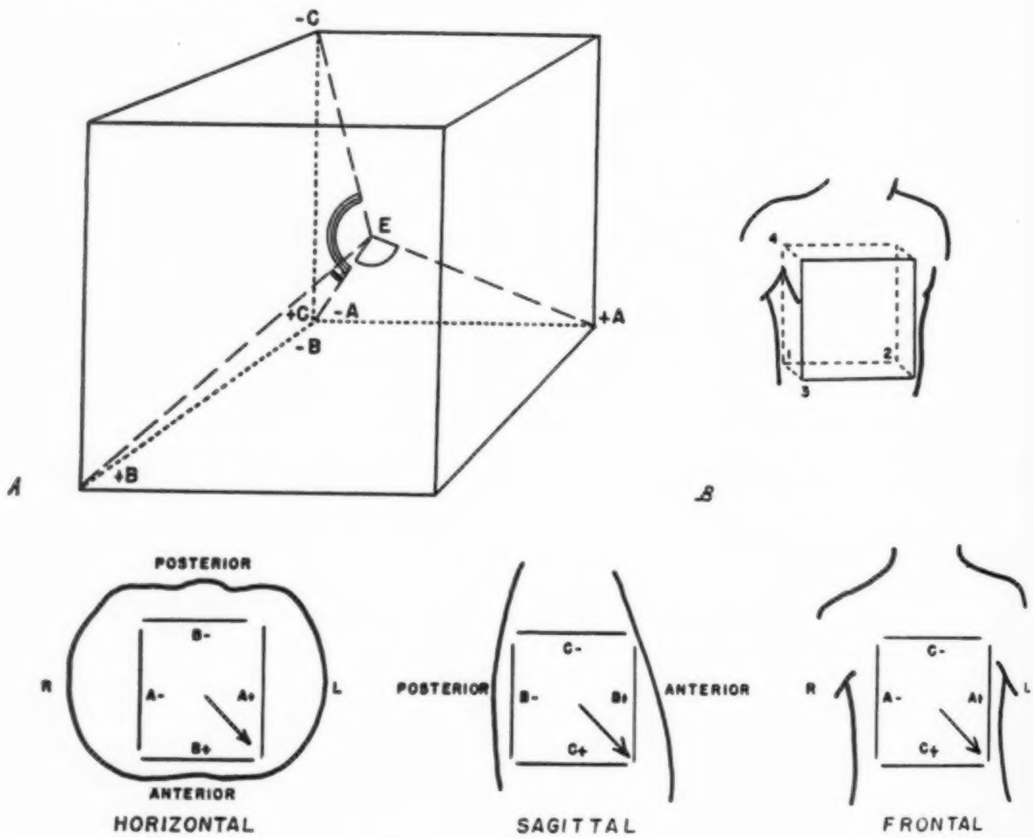

Fig. 1.—*A*, Diagram illustrates the relationship of the dipole *E* to the bipolar component leads $-A+A$, $-B+B$, $-C+C$. *B*, Superimposition of the cube arrangement on the thorax. Electrodes are placed at points *1*, *2*, *3*, and *4* with polarity as indicated in Fig. 1,*A*. *C*, The plates of the oscilloscopes, their connections to the bipolar component leads, and their relation to the thorax are shown schematically.

The technique employed by us is as follows:

It is assumed that the central origin (E) of all electromotive forces generated by the heart is located in the center of a sagittal plane passing just to the left of the sternum at the level of the fourth intercostal space. Four electrodes are placed on four of the corners of a cube having this point at its center and

being as equidistant from E as the anatomy of the thorax allows (Figs. 1,*A* and *B*).

The electrodes are located as follows: (1) one electrode (No. 1 of Fig. 1,*B*) with three cable connections is placed near the right posterior axillary line at the level of the first and second lumbar vertebrae. The remaining three electrodes are placed (2) in the left posterior axillary line (No. 2 of Fig. 1,*B*), (3) vertically over the right scapula (No. 4 of Fig. 1,*B*), and (4) sagitally, anteriorly, in the right anterior axillary line (No. 3 of Fig. 1,*B*). A projection of the assumed center of electromotive forces should evenly divide the distances between the electrodes. With experience the electrodes can be applied with great rapidity and accuracy.

Vector presentation is accomplished by means of three bipolar leads: (1) horizontal component −A, +A (The signs indicate the selected polarity); (2) vertical component −C, +C; and (3) sagittal component −B, +B.

The polarity at the electrodes is such that the negative pole of the vertical component lead (−C) is at the right shoulder, while the negative poles of the horizontal (−A) and sagittal (−B) component leads are located at the right posterior axillary line at the level of the first or second lumbar vertebra (Fig. 1,*A*).

The projection termed "frontal" should more accurately be called "posterior vertical," but for the present we have retained the time-honored term in order to avoid confusion.

The three amplifiers of a Technicon cardiograph are employed and are arranged to feed directly the plates of a specially designed triple cathode ray oscilloscopic arrangement (Tribeam Technicon Scope). The connections to the plates and the polarity selected are indicated in Fig. 1,*C*. The polarity used in the present study is that suggested by Einthoven and is opposite in direction to that of Mann and Duchosal and Sulzer. Although the latter investigators are correct in their reasoning for reversing the polarity, the Einthoven polarity has been adopted in the present study in order to simplify the presentation of findings.

The amplification is the same in each of the three channels, and the introduction of 1 mv. into the circuit causes the beam to deviate at an angle of 45 degrees downward and to the observer's right.

All records are taken with the patient in the horizontal position. What little alternating-current interference is present can be eliminated by balancing the circuits. A three-step amplifying selector, which is standard equipment with the Technicon cardiograph, permits selection of the optimal amplitude for recording. Different amplifications may be chosen for individual optimal recording of the QRS, RT, T, and P vectors. All three projections are recorded simultaneously with a 4 by 5 inch cut-film camera, the shutter speed being adjusted at either 0.5 or 1 second, depending upon the cardiac rate of the patient.

In the future it is planned to use an automatic repeater camera, allowing $2\frac{1}{2}$ by 5 inch records to be obtained at a rate of three to four per second. The same camera, with a continuous movement of the film in a downward direction in relation to the scope-image, will also permit the recording of the direction of rotation of the vector loops and more distinct separation of the atrial and ventricular loops.

A blue, sensitive, single-coated x-ray film* was found most satisfactory for recording the oscilloscope images because of the high blue sensitivity and ease of handling in the darkroom.

The sequence of projections as presented in this and subsequent publications depended upon technical necessities while recording the direction of the vector loops simultaneously with a high-speed moving-picture camera. Application of the electrodes and recording of the vector projection in three planes usually requires no more than five minutes.

The amplifiers of the Technicon cardiograph, in conjunction with the triple cathode ray oscilloscope arrangement, when correctly dampened, have a linear frequency response up to 140 cycles per second and as low as ½ cycle per second (the lower limit of the frequency oscillator used for testing). Time recordings are impressed upon the record by intensity modulation of the cathode ray beam by means of an electric tuning fork at a fixed rate of 400 cycles per second.

The bipolar component leads and conventional leads are recorded with the direct writing recorder of the Technicon cardiograph.

DISCUSSION

Simplicity of vectorial presentation of the electromotive forces produced by cardiac action was not the only reason for preferring the cube arrangement of electrode placement to the tetrahedral or sagittal triangular arrangements.

The exactness of mathematical deductions and physical principles, as applied to the analysis of the electromotive force produced by the heart, is limited by the various physical properties of the heart and its surrounding tissues. Caution is essential when applying theoretical deductions to experimentation because of the complexity of the actual conditions encountered and the inability to subject all of these to theoretical analysis. Decisions of investigators may vary, depending upon whether it is desired to apply the new method to the explanation of facts already known or to explore new aspects and horizons. This factor may be decisive in the choice of various approaches by different investigators.

When the tetrahedral arrangement is used for recording spatial vectorcardiograms, the frontal vertical projection can be closely correlated with the standard and unipolar extremity leads, whereas the sagittal loop cannot be correlated with patterns obtained by routine electrocardiography. If one records a vector projection produced by the horizontal component (Lead I) and the sagittal component (VB), an image of a tilted horizontal projection is as often obtained as that of a tilted frontal plane. Therefore, analysis of the size and direction of the forces acting in the horizontal plane requires the construction of wire models, which are cumbersome, or the use of stereoprojection which is complicated and unreliable. It would be difficult, if not impossible, to reconstruct the time intervals, which are extremely important.

There are other objections to adhering to the plane formed by the right arm, left arm, and left foot leads as the key projection for spatial vectorcardiography. When Einthoven, Fahr, and de Waart[13] proposed the equilateral triangle for the formulation of the manifest potential difference, they were fully aware

*Eastman Kodak, Rochester, N. Y.

that this method was only an approximation of the truth. Any geometric arrangement for spatial vectorcardiography based on this formulation, as extended to the equilateral tetrahedron, requires assurance that this triangle is practically equilateral and that it represents correctly the forces parallel to the frontal plane. The validity of either supposition[14,15] is subject to much question.

The determination of the respective coefficients or standardization factors which might correct inequalities of the limbs of the triangle appears impractical. For example, in cardiac enlargement, right or left, there is a pronounced inequality of the coefficients, and the resulting geometric representation has little semblance to an equilateral triangle. Reconstruction of spatial vectorcardiograms on the basis of a sagittal plane assumed to be at right angles with the frontal plane permits only an approximation of the actual configuration and position of the cardiac vector. That this is not reliable will be shown in publications to follow.

Another objection to the use of the tetrahedral arrangement is the occasional error caused by the position of the back electrode. In the majority of instances the general form and rotation of the vector loops in the sagittal plane obtained by this method were essentially similar to those obtained with a modification of the sagittal triangle, as suggested by Arrighi,[12] or by the cube system. At times, however, the tetrahedral sagittal arrangement produced a rotation in the opposite direction, i.e., facing "cavity of shell" instead of "surface of shell," or vice versa.

The sphere is the ideal geometric approach for measuring the vectors of a given electromotive field force. The limbs connecting points at equal distance along the surface of the sphere with the center of the sphere (E) would subtend angles of equal size and therefore indicate comparable quantities of the field force. The eight corners of a cube represent eight equally distant points on the surface of a sphere. The dipole E, which is theoretically in the center of the cube, is equidistant from each of the eight points (Fig. 1,*A*). We have encountered little difficulty in adapting the cube arrangement to the human thorax, whereas Duchosal and Sulzer felt obliged to utilize the rectangular solid of a "double cube." The vertical and horizontal components can always be arranged equal in length. The sagittal component is often somewhat shorter, but this difference rarely exceeds 15 per cent. This may result in a slight "compression" of the sagittal projection of the vector which is not significant. A linear increase of standardization by the percentage of difference from the other component leads would correct for this discrepancy (1.1 standardization units per millivolt instead of 1.0 per millivolt for a given discrepancy of 10 per cent). In our experience such a correction alters the contour or position of the spatial vector too little to be of concern in our present state of knowledge. Therefore, we have not made this correction as a rule.

Each electrode is sufficiently distant from the dipole E in the cube arrangement for the exploration of its field. Furthermore, the tissue interposed between E and the four electrodes is predominantly lung tissue. Therefore, the coefficients for all four electrodes are as closely equal as can be achieved under biological experimental conditions.

An important reason for selecting the cube arrangement was the close correlation of the horizontal projection of the vector loop with the unipolar chest leads recorded at similar levels. Since unipolar leads record the cardiac electromotive field force along a line drawn from the exploring point through E, an analysis of multiple thoracic leads should make it possible to check the accuracy

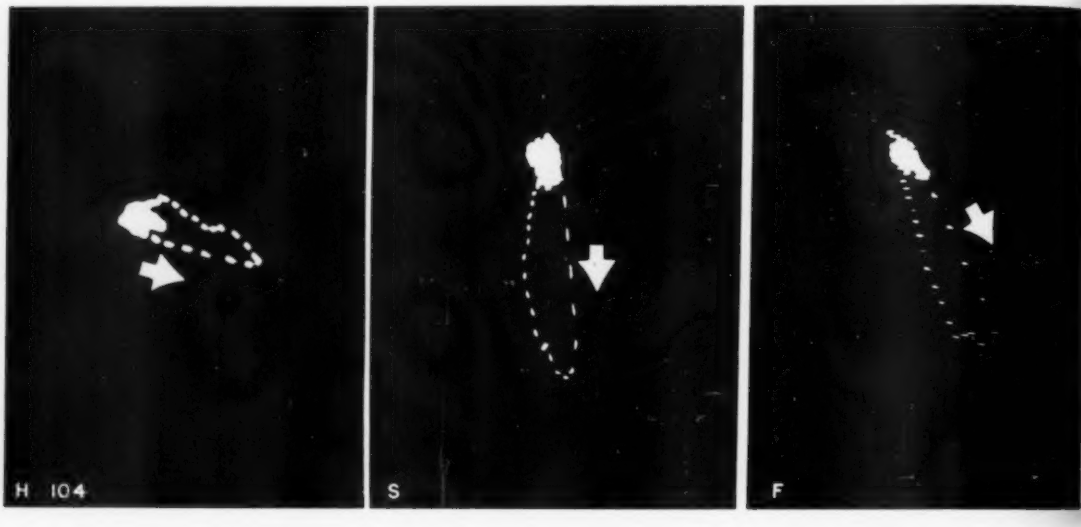

Fig. 2*A*.—Normal 26-year-old man. Frontal (posterior vertical), sagittal, and horizontal projection recorded simultaneously with cube arrangement. The timing and direction of the horizontal projection closely conform to unipolar chest leads, anteriorly as well as posteriorly.

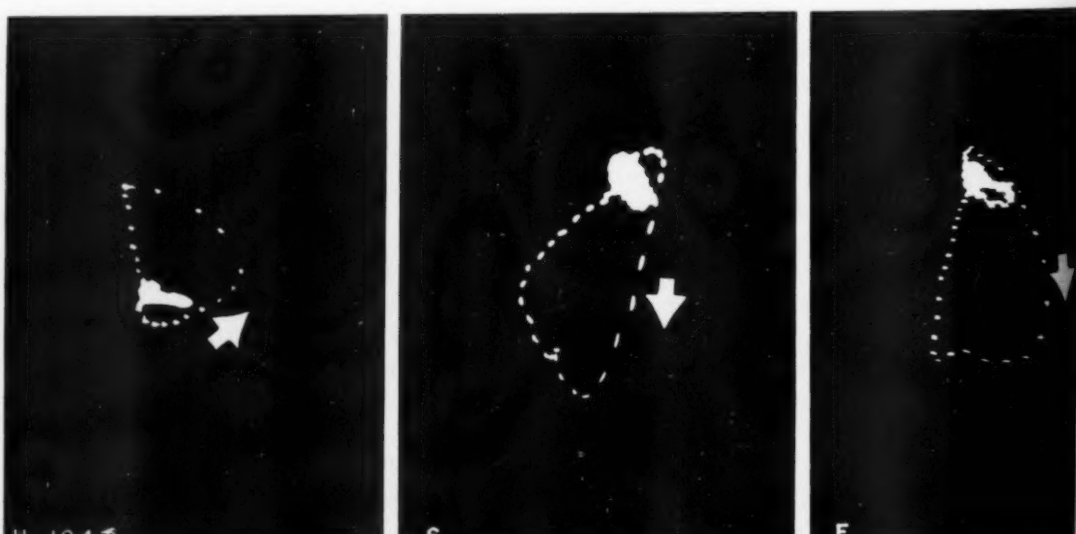

Fig. 2*B*.—Simultaneously recorded frontal, sagittal, and "tilted frontal" plane, using the tetrahedral arrangement. General configuration of curves and indication of spatial position are similar to those of the cube arrangement.

of the spatial position of the vectorcardiogram as recorded by the cube system. The direction of the electromotive field force (+ and −) and the timing of even minute details of QRS and T waves were found to coincide extremely well. Conversely, almost the exact configuration of all chest leads could be predicted from the horizontal loop. This accuracy was somewhat less marked as for the

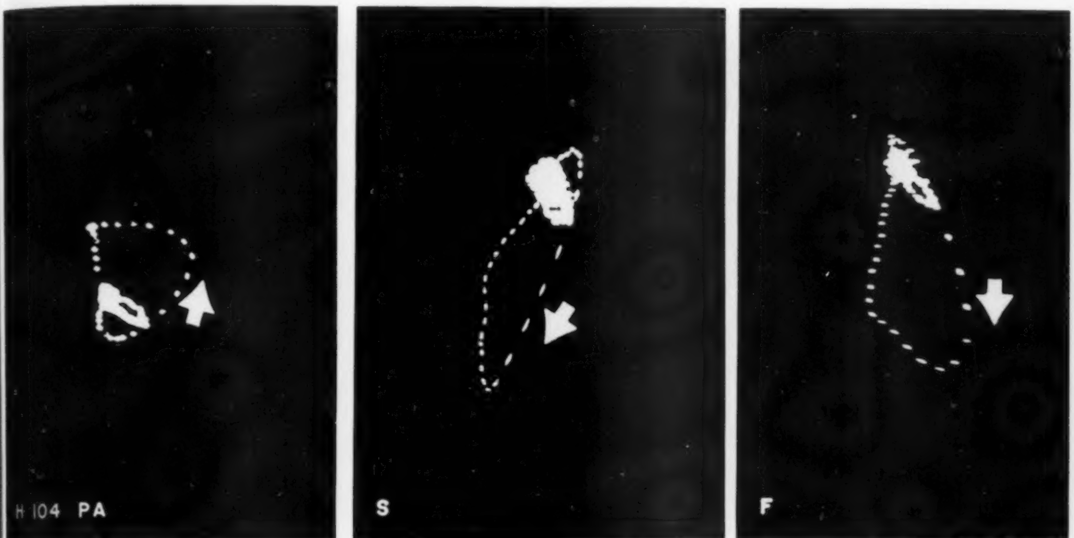

Fig. 2*C*.—Using a sagittal triangle, the curves and their spatial orientation are again similar to those obtained with the cube or tetrahedral arrangement. The slight difference of the frontal projection from that in Fig. 2*B* is due to positional variation. It is emphasized that this close similarity of spatial orientation is uncommon.

Fig. 3*A*.—A 34-year-old woman with aortic stenosis and insufficiency. Simultaneous records of frontal, sagittal, and horizontal projection of the spatial vector using the cube arrangement. The horizontal curves correspond well in timing and direction with the unipolar chest leads.

absolute voltages of R and S waves in leads recorded close to the heart and therefore close to E (Leads V_{R4} to V_7), but did apply to posterior and right lateral chest leads (Figs. *2A*, *3A*, and *4A*).

Similar analyses in cases where the tetrahedron or sagittal triangle was used and where Lead I and the sagittal component gave the projection a tilted horizontal plane resulted in poor correlation. In a large comparative series the

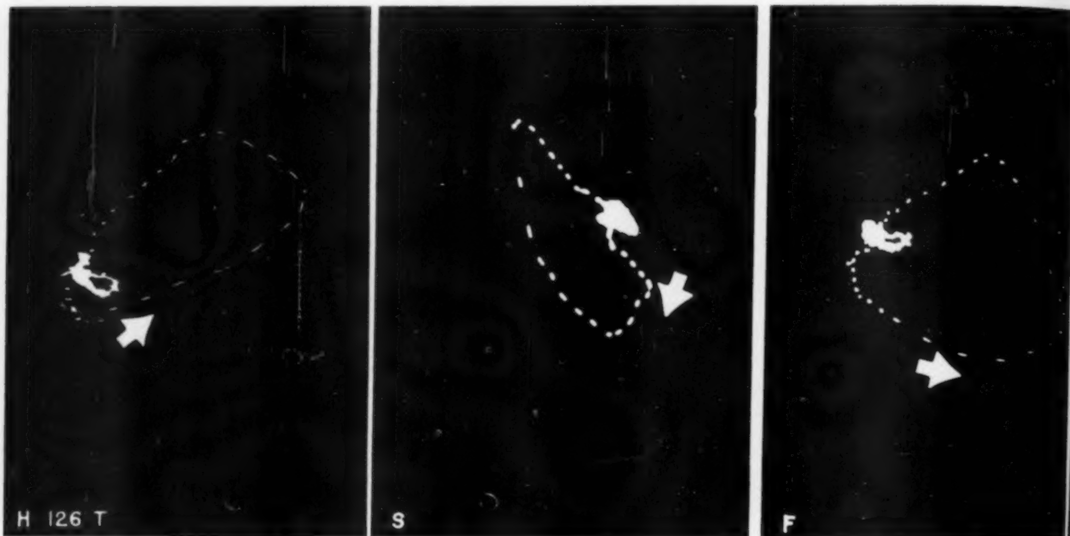

Fig. 3*B*.—Using the tetrahedral arrangement, the main direction of the "tilted horizontal" plane and the spatial vector is about 20 degrees more to the left posteriorly.

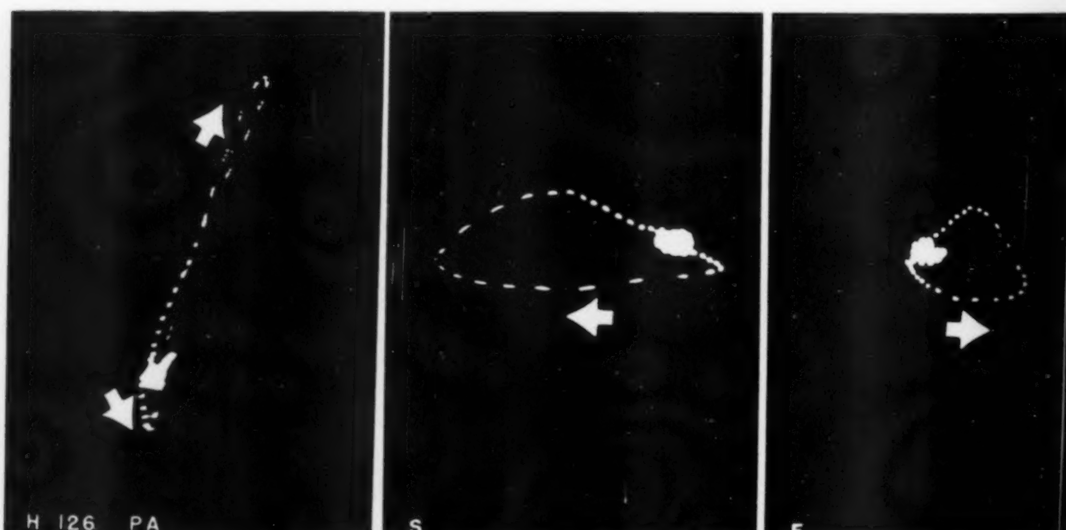

Fig. 3*C*.—With the sagittal triangle (one-half standardization of 3*A* and 3*B*) the sagittal projection indicates the disproportionate size of the sagittal component, leading to even greater discrepancy of the spatial orientation from that indicated by unipolar chest leads.

deviation was as much as 35 degrees and at times even greater (Figs. *2B*, *2C*, *3B*, *3C*, *4B*, and *4C*).

Duchosal and Sulzer's[8] arrangement of the "double cube" was well analyzed by Cabrera.[16] He showed that, because of the unequal size of the internal angle of the vertical component, the size of forces was represented unequally. The horizontal projection is identical with that of the cube.

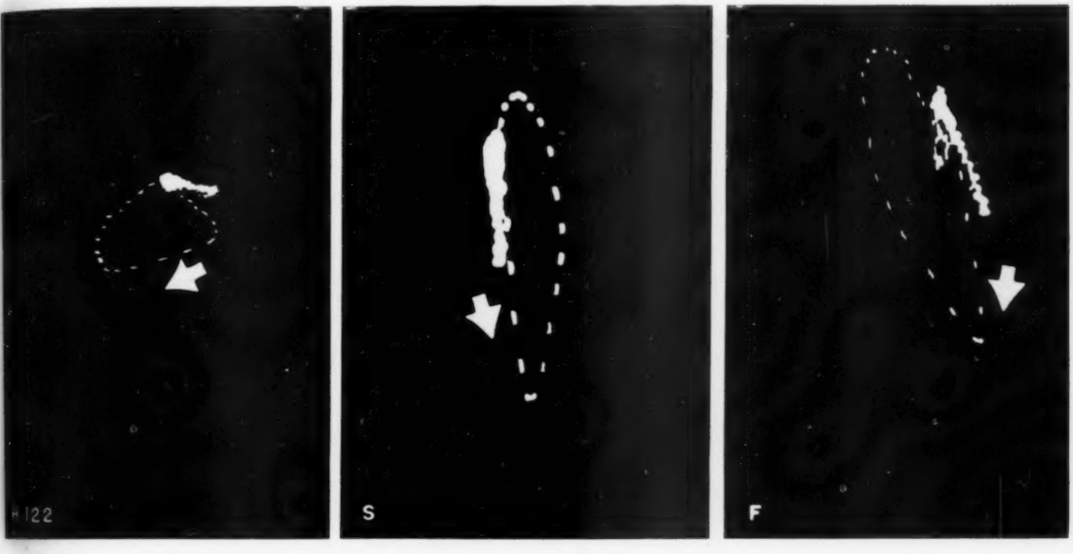

Fig. 4*A*.—A 12-year-old boy with Eisenmenger's complex. Frontal, sagittal, and horizontal projection using the cube arrangement. The timing and direction of the horizontal projection gave close correlation with that of the unipolar chest leads around the chest.

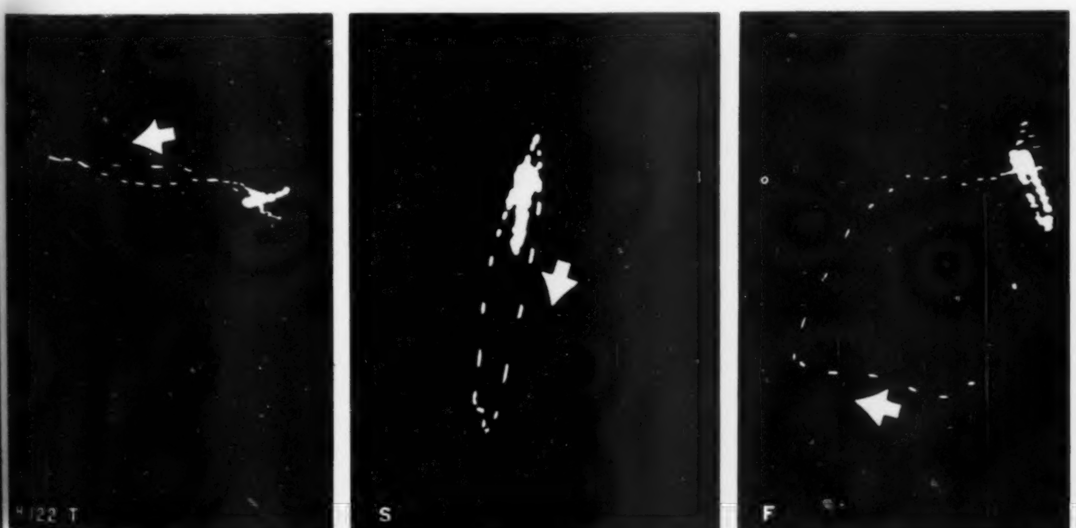

Fig. 4*B*.—The use of the tetrahedral arrangement resulted in a right posterior orientation and a clockwise rotation in the sagittal projection. The orientation thus is different from that shown by the cube arrangement, sagittal triangle, and unipolar chest leads.

It may seem unnecessary to record three planes simultaneously as was done in the present study since only two are required for spatial reconstruction. However, it is desirable to avoid the cumbersome and inaccurate construction of models or stereoprojection unless they are used for instruction purposes only. The simultaneous presentation of the cardiac vectors in three planes permits spatial orientation with great facility.

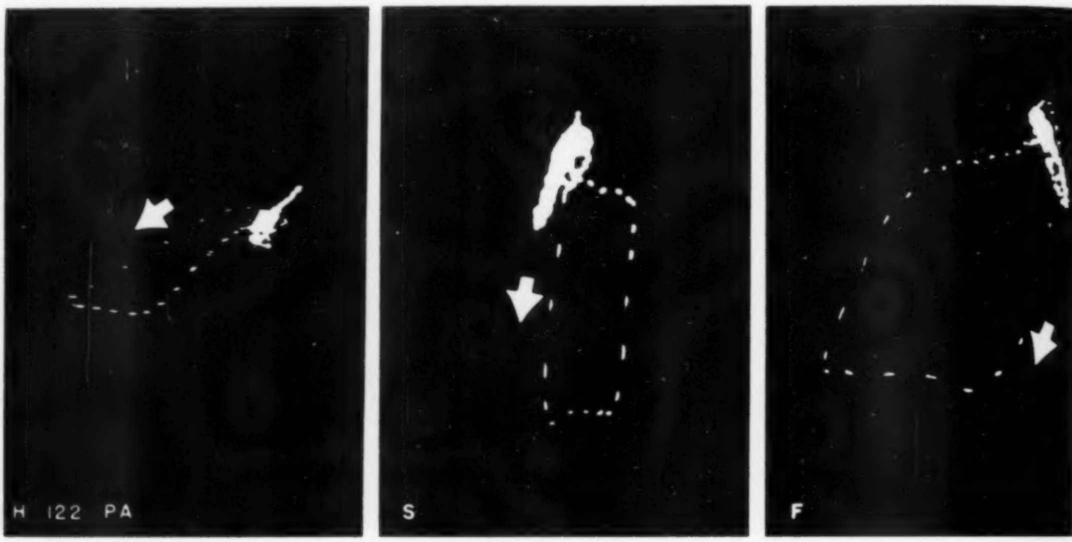

Fig. 4C.—Using a sagittal triangle for recording the forces as projected to that plane, a spatial orientation more similar to that of the cube arrangement is obtained. The most constant correlation with unipolar chest leads, in respect to spatial orientation, was obtained with the cube arrangement.

SUMMARY

A technique for the simultaneous recording of a frontal, sagittal, and horizontal vectorcardiogram is described. The geometric arrangement selected for electrode placement is that of a cube. The reasons for preferring the cube arrangement to the equilateral tetrahedron are discussed.

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SPATIAL VECTORCARDIOGRAPHY: LEFT BUNDLE BRANCH BLOCK AND LEFT VENTRICULAR HYPERTROPHY. II.

LEONARD SCHERLIS, M.D.,* AND ARTHUR GRISHMAN, M.D.

NEW YORK, N. Y.

WITH THE COOPERATION OF AVERY A. SANDBERG, M.D.,** AND JOSEPH DVORKIN, M.D.

THE electrocardiographic distinction between left ventricular hypertrophy and incomplete and complete left bundle branch block is at times difficult when only the usual electrocardiograms are available. According to Wilson and his co-workers,[1] left bundle branch block can be diagnosed with certainty only when the QRS complex is abnormally long, the epicardial surface of the homolateral ventricle is activated abnormally late, and the cavity of this ventricle is initially positive. The criteria for the electrocardiographic diagnosis of left ventricular hypertrophy include increased amplitude of the R wave, an abnormally late peak of the R wave over the left side of the precordium, and, frequently, an increased duration of the QRS complex.[1] The left ventricular cavity is negative throughout the spread of the excitation wave in left ventricular hypertrophy.[2] However, by the usual electrocardiographic methods, it is not possible to obtain sufficient information on cavity potentials, and hence at times it is difficult to distinguish between left ventricular hypertrophy, incomplete left bundle branch block, and complete left bundle branch block.

Catheterization of the human left ventricle has confirmed the finding reported previously in animals[3,4,5] that there is early positivity of the left ventricular cavity in left bundle branch block[6] as compared to negativity if conduction is not impaired.[2,6] Similar results have been obtained by means of esophageal leads at atrial level reflecting left ventricular cavity potentials.[7,8] At this level, in left ventricular hypertrophy, the ventricular pattern was QS in configuration while in left bundle branch block equiphasic RS patterns were obtained.

Mann[9,10] and Wilson and Johnston,[11] utilizing only the frontal plane as presented by the Einthoven triangle, described the vector loops found in several conditions including left bundle branch block. More recently, the pattern of left bundle branch block has been described as recorded by spatial vectorcardiography.[12-15] However, in these studies the distinction between left ventricular hypertrophy, incomplete left bundle branch block, and complete left bundle branch block has not always been possible since only routine electrocardiograms were utilized. As a result, various vectorcardiographic patterns have been described in left bundle branch block.

From the Cardiographic Department and Cardiovascular Research Group, The Mount Sinai Hospital, New York.

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*Trainee of the National Heart Institute.

**Fellow of the Dazian Foundation for Medical Research.

Since the vector loop as recorded by the cathode ray oscillograph represents the advancement of the terminus of an instantaneous vector during the time consumed by the spread of the wave of accession, any delay in this spread should be apparent from a study of the vector loop. The present study was undertaken in an effort to obtain further information upon the spatial vectorcardiogram in left bundle branch block and left ventricular hypertrophy. Distinction between these two conditions was first made by utilizing esophageal records taken at atrial level reflecting left ventricular cavity potentials. The simultaneous recording of vectorcardiograms in the frontal, sagittal, and horizontal planes afforded an excellent means for studying the problems of conduction delay. Automatic interruption of the beam permitted a time analysis of the spread of the wave of excitation.

METHODS

The group of patients included in this study consisted of fourteen persons with electrocardiographic evidence of left bundle branch block, twenty persons with electrocardiographic evidence of left ventricular hypertrophy, and two persons with intermittent left bundle branch block. The electrocardiographic criteria for the initial selection of these cases were those of Wilson and co-workers.[1] Standard, unipolar extremity, and six unipolar precordial leads were recorded for each patient. Esophageal electrocardiograms were also recorded at fifteen levels in eleven patients with left bundle branch block and in ten patients with left ventricular hypertrophy. The method used for recording multiple esophageal electrocardiograms has been given in detail elsewhere.[16]

Vectorcardiograms were then recorded utilizing, in principle, the method of Duchosal and Sulzer.[14] The details of the method employed in the present study are being reported separately.[17] The vectorcardiograms in the horizontal, sagittal, and frontal planes were simultaneously visualized on a three-beam Technicon Scope and photographed on one film. The direction of rotation of the cathode ray beam was noted and recorded for each plane by several observers, and motion pictures were occasionally taken. The Technicon Cardiograph was used throughout.

An electrical tuning fork with a frequency of 400 cycles per second interrupted the recording of the beam each 0.0025 second and thus permitted a time analysis of the record.

For the simultaneous recording of the spatial vectorcardiogram in each of three planes, three pairs of electrodes were utilized: *A* (horizontal), *B* (sagittal), and *C* (vertical) (Fig. 1). The placement of the electrodes was as follows:

1. *A minus, B minus, and C plus*: a common electrode, located at about the level of the second lumbar vertebra in the right posterior axillary line;
2. *A plus*: at the level of the second lumbar vertebra in the left posterior axillary line (i.e., at the same level as 1);
3. *B plus*: over the lower rib margin in the right anterior axillary line (i.e., in the same plane as 1 and 2);
4. *C minus*: over the right shoulder posteriorly (i.e., in the same plane as 1 and 3).

These locations may be considered as representing four of the corners of a cube.

The components of the horizontal plane were thus recorded by the *A* and *B* electrodes; of the sagittal, by *B* and *C*; and of the frontal, by *A* and *C*. The introduction of 1 mv. into this circuit was represented in each plane by the movement of the cathode ray beam at a 45 degree angle downward and to the observer's right (Fig. 1). The standardization employed was the same in each plane and was recorded in simultaneous electrocardiograms representing the three pairs of electrodes.

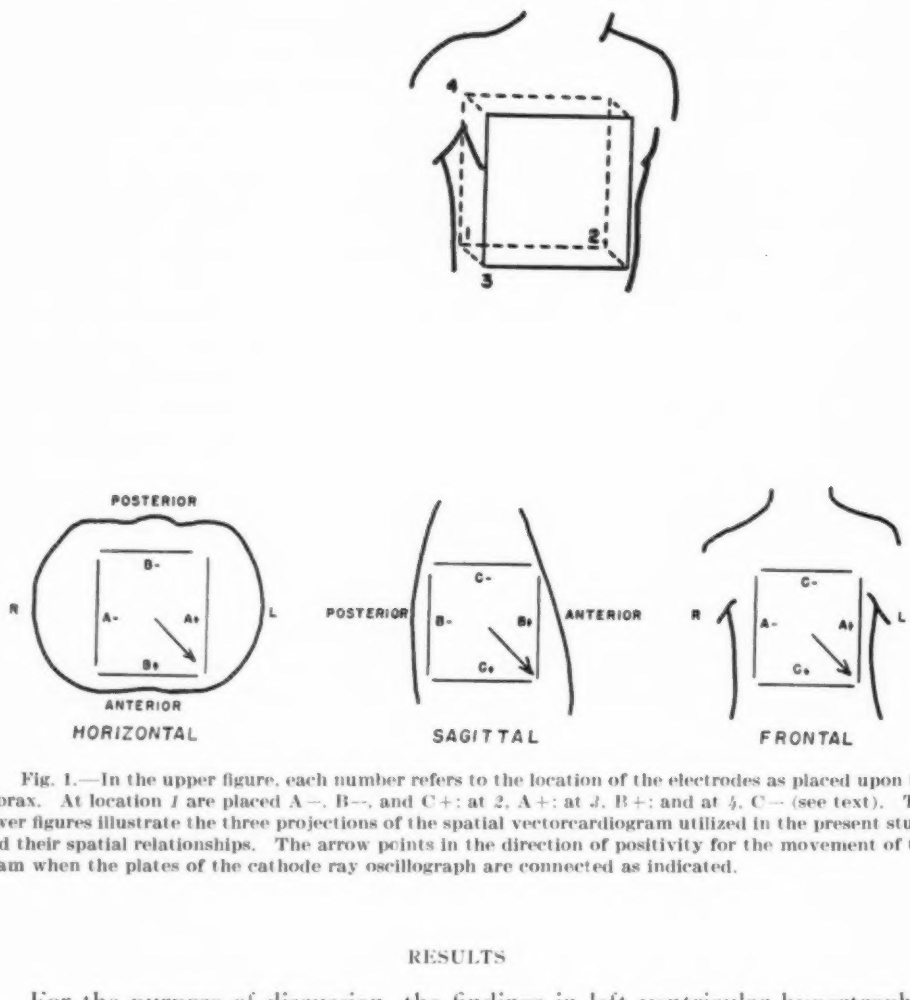

Fig. 1.—In the upper figure, each number refers to the location of the electrodes as placed upon the thorax. At location *1* are placed A−, B−, and C+; at *2*, A+; at *3*, B+; and at *4*, C− (see text). The lower figures illustrate the three projections of the spatial vectorcardiogram utilized in the present study and their spatial relationships. The arrow points in the direction of positivity for the movement of the beam when the plates of the cathode ray oscillograph are connected as indicated.

RESULTS

For the purpose of discussion, the findings in left ventricular hypertrophy, left bundle branch block, and intermittent left bundle branch block are presented separately.

Left Ventricular Hypertrophy.—Marked left axis deviation was usually present in the standard leads of the twenty persons in this group. The left precordial electrocardiograms were characterized by increased amplitude of the R wave, depression of the RS-T segment, and inverted T waves. The intrinsicoid

deflection was delayed in V_5 and V_6. In no electrocardiogram was there any evidence of myocardial infarction.

In ten of these persons, esophageal electrocardiograms were recorded at each of fifteen levels from the subdiaphragmatic to the supracardiac levels. The onset of the intrinsicoid ventricular deflection below atrial level was consistently later over the posterobasal aspect of the left ventricle than the onset of the intrinsicoid ventricular deflection over the anterolateral aspect as recorded in V_5 or V_6. At atrial level, as characterized by the presence of an intrinsic atrial deflection, the ventricular pattern was QS or Qr in configuration in each instance, and the RS-T segment was usually elevated (Fig. 2).

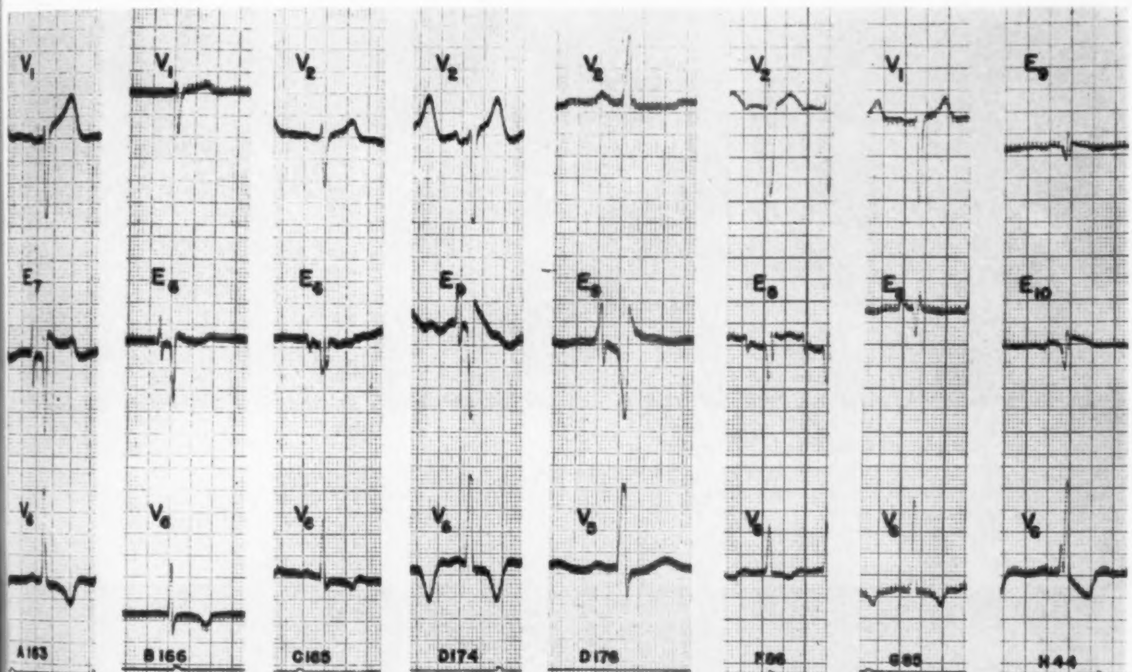

Fig. 2.—The electrocardiograms from eight of the patients with left ventricular hypertrophy. *E* is the esophageal pattern recorded at atrial level and represents left ventricular cavity potentials. It is preceded by an intrinsic atrial deflection. All were recorded at normal speed except D 176 which was recorded at twice normal speed. The esophageal lead was recorded simultaneously with the precordial or standard leads. Note the initial negativity present in the esophageal leads.

The vectorcardiograms of these twenty persons demonstrated several similarities (Figs. 3*A*, 3*B*, 4*A*, and 4*B*). The inscription of the QRS sÊ loop did not show any delay. Such delay would be manifested by the close grouping together of the time markings in the loop in all three planes. While any one loop in the three simultaneously recorded planes might present the appearance of delay, its absence in the other two planes would indicate that a tangential view of the loop was presented with the perspective such that the portions of the loop appeared close together.

The frontal plane QRS sÊ loops were inscribed in the I or VI sextants of the triaxial system of Bayley[18] and in a counterclockwise direction as viewed by the observer in seventeen of the twenty patients. In the remaining three cases, the loop was narrow and "figure 8" in configuration, with the distal portion inscribed in a clockwise direction. The QRS sÊ loop was usually open at its terminal portion. The T sÊ loop was usually opposite in direction to the QRS sÊ loop.

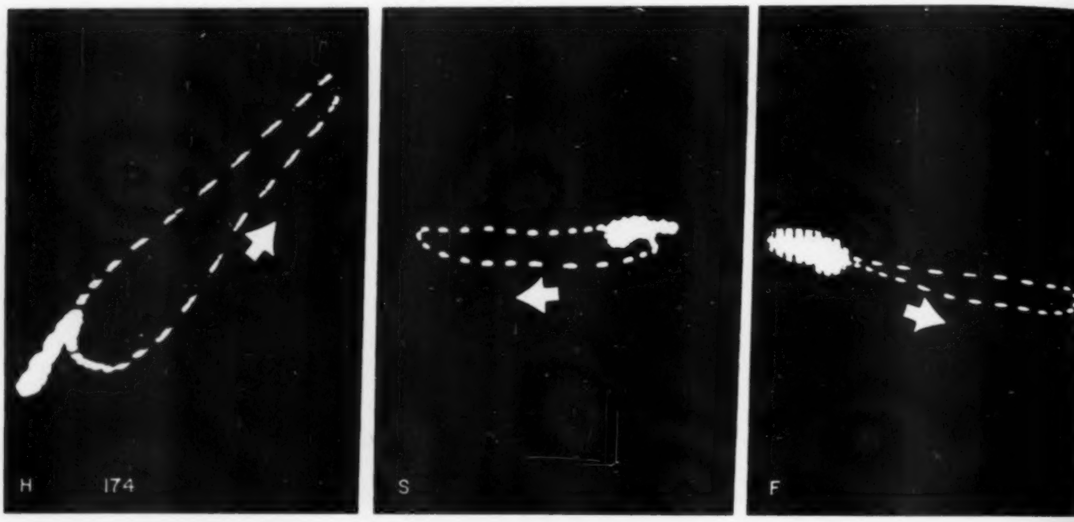

Fig. 3*A*.—Simultaneous horizontal (*H*), sagittal (*S*), and frontal (*F*) vectorcardiograms in left ventricular hypertrophy, Case 174 (see Fig. 2, D 174, for esophageal lead at atrial level). The arrow indicates the direction of inscription of the loop. For ease in visualization, each loop may be considered as imposed upon the body outlines in Fig. 1. The smaller loop is the T sÊ loop. Each segment of the loop represents 0.0025 second.

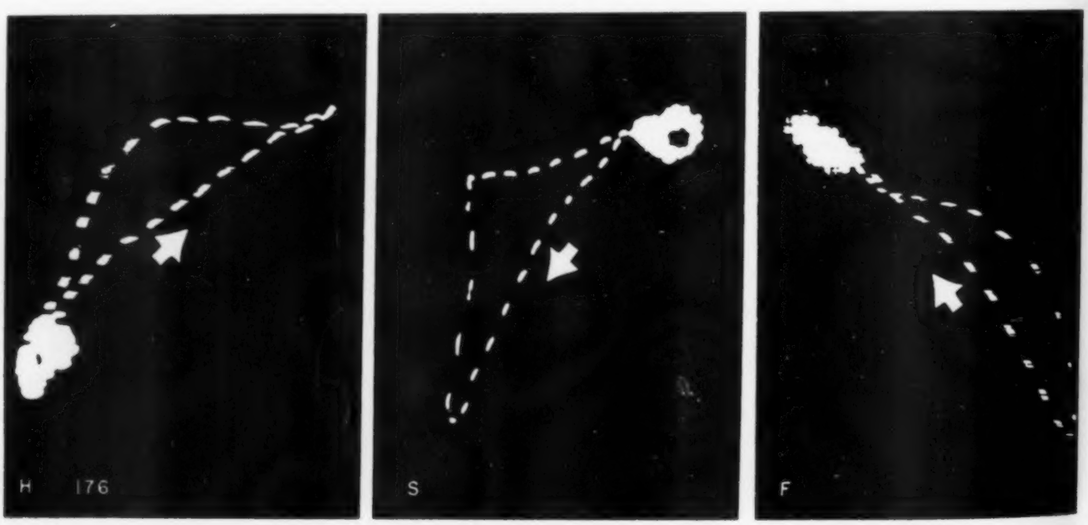

Fig. 3*B*.—Horizontal, sagittal, and frontal vectorcardiograms in left ventricular hypertrophy, Case 176 (see Fig. 2, D 176, for esophageal lead at atrial level).

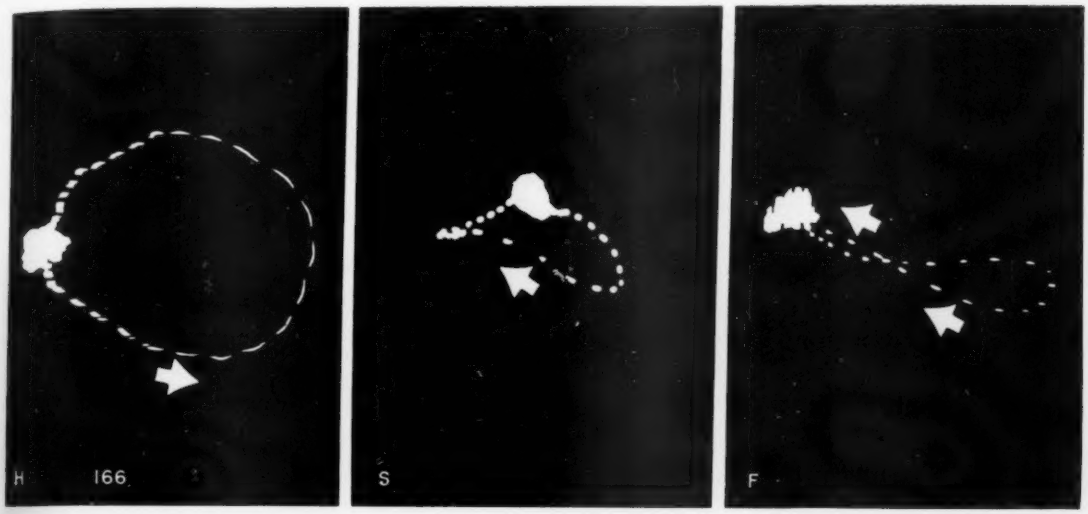

Fig. 4*A*.—Vectorcardiograms in left ventricular hypertrophy, Case 166 (see Fig. 2, B 166).

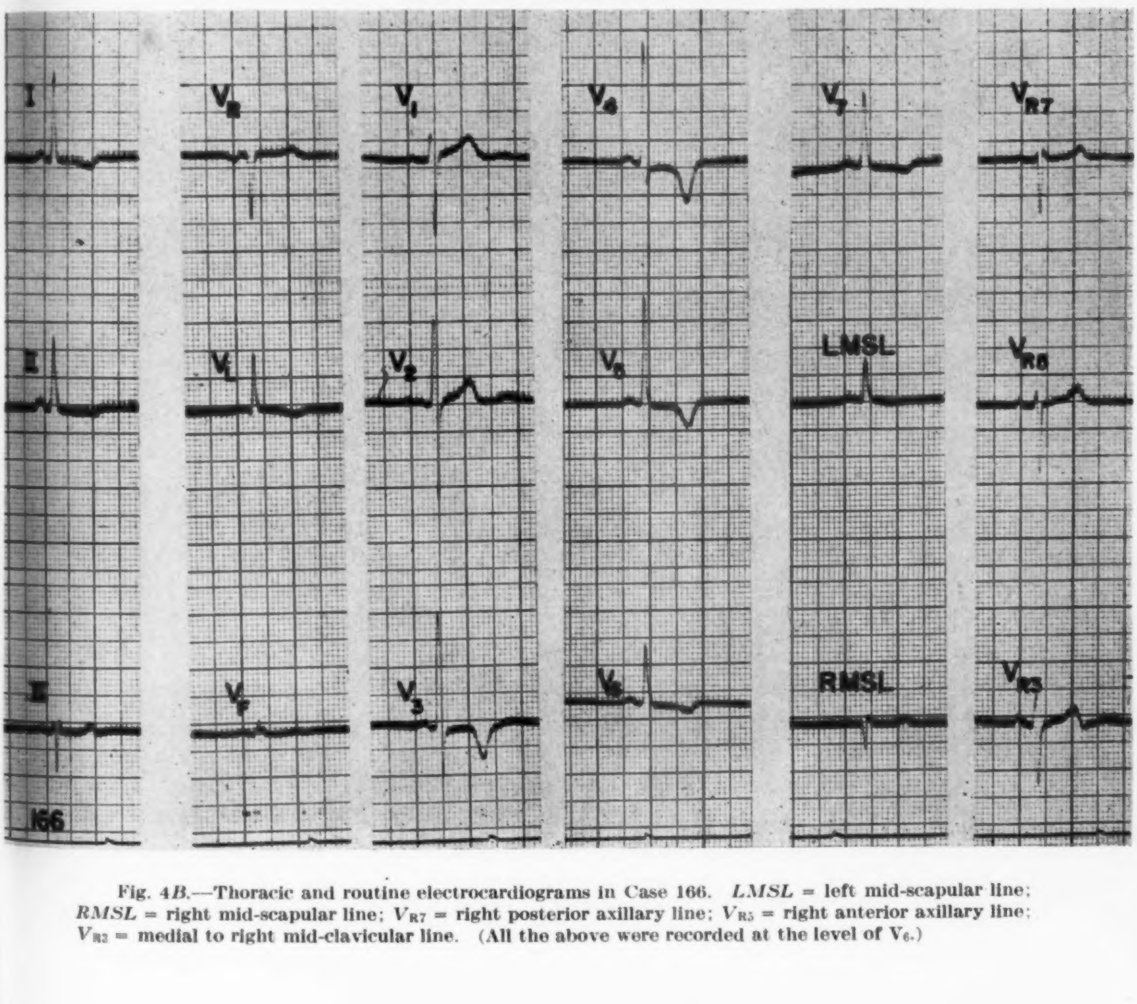

Fig. 4*B*.—Thoracic and routine electrocardiograms in Case 166. *LMSL* = left mid-scapular line; *RMSL* = right mid-scapular line; V_{R7} = right posterior axillary line; V_{R5} = right anterior axillary line; V_{R3} = medial to right mid-clavicular line. (All the above were recorded at the level of V_6.)

The sagittal plane QRS sÊ loops were consistently inscribed in a clockwise direction. The position of the major portion of the loop in twelve of the records was downward and posterior, in six upward and posterior, and in two upward and slightly anterior. Esophageal records were available in three of the patients in whom the QRS sÊ loop was inscribed in an upward direction in the sagittal plane. In this group, the major deflection of the QRS complex was an R wave at supracardiac levels as contrasted to the QS or Qr pattern recorded in other patients.

In the horizontal plane, the QRS sÊ loops were inscribed posteriorly and to the left in each instance. The loops were consistently inscribed in a counterclockwise direction and were usually open at the terminal portion. The T sÊ loop was usually opposite in position to the QRS sÊ loop.

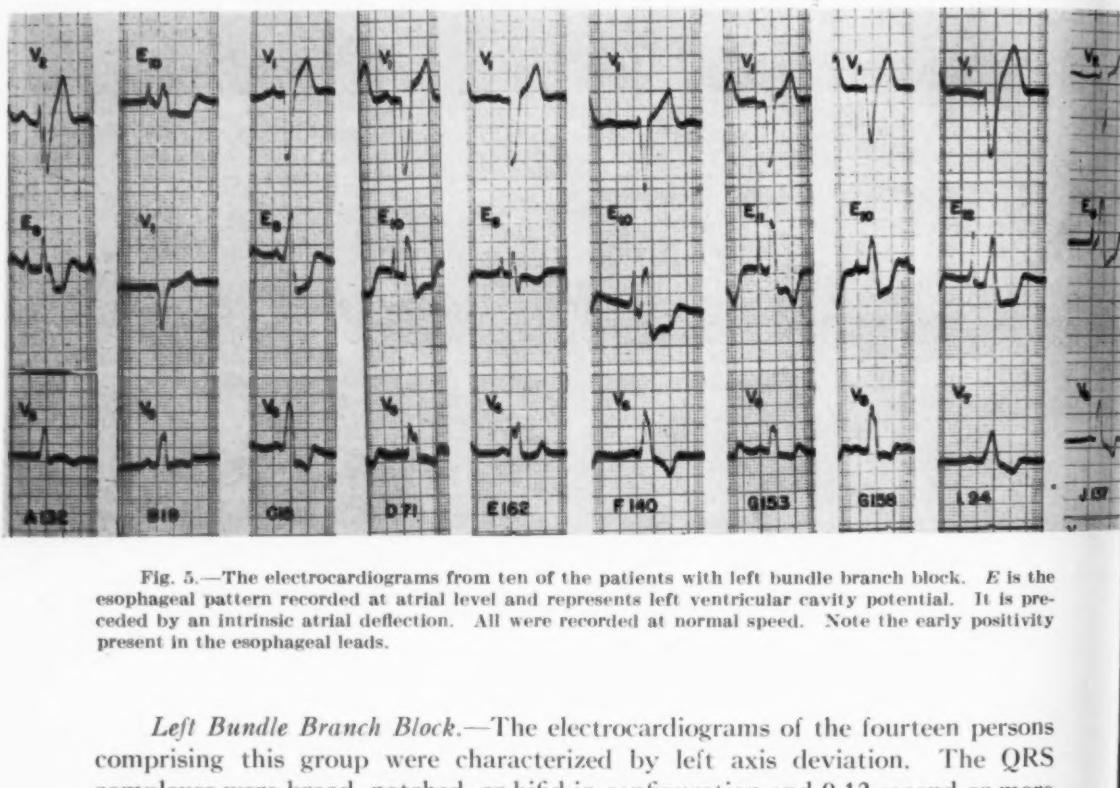

Fig. 5.—The electrocardiograms from ten of the patients with left bundle branch block. *E* is the esophageal pattern recorded at atrial level and represents left ventricular cavity potential. It is preceded by an intrinsic atrial deflection. All were recorded at normal speed. Note the early positivity present in the esophageal leads.

Left Bundle Branch Block.—The electrocardiograms of the fourteen persons comprising this group were characterized by left axis deviation. The QRS complexes were broad, notched, or bifid in configuration and 0.12 second or more in duration, with a marked delay in the appearance of the intrinsicoid deflection in the left precordial leads. The T waves were opposite in direction to the QRS complexes, and the RS-T segments were depressed.

In eleven of these patients, esophageal electrocardiograms were recorded. Below atrial level, the onset of the intrinsicoid ventricular deflection was consistently earlier over the posterobasal aspect of the left ventricle as recorded by esophageal electrodes than over the anterolateral aspect as recorded simultaneously in V_5 or V_6. At atrial level, as characterized by the presence of an intrinsic atrial deflection, the ventricular pattern was RS in configuration except

for a few records in which a minute Q wave preceded the RS pattern. The RS-T segment at this level was markedly depressed in each instance (Fig. 5).

The vectorcardiograms in all planes revealed distinct delay in the inscription of the QRS sÊ loop in the fourteen persons in this group (Figs. 6*A*, 6*B*, 7*A*, and 7*B*). This delay was usually present in the mid-portion of the loop, but in one instance, the delay occurred slightly earlier and in another slightly later. The delay was manifested by the extremely close position of the interrupted segments of the QRS sÊ loops in these portions of the loops.

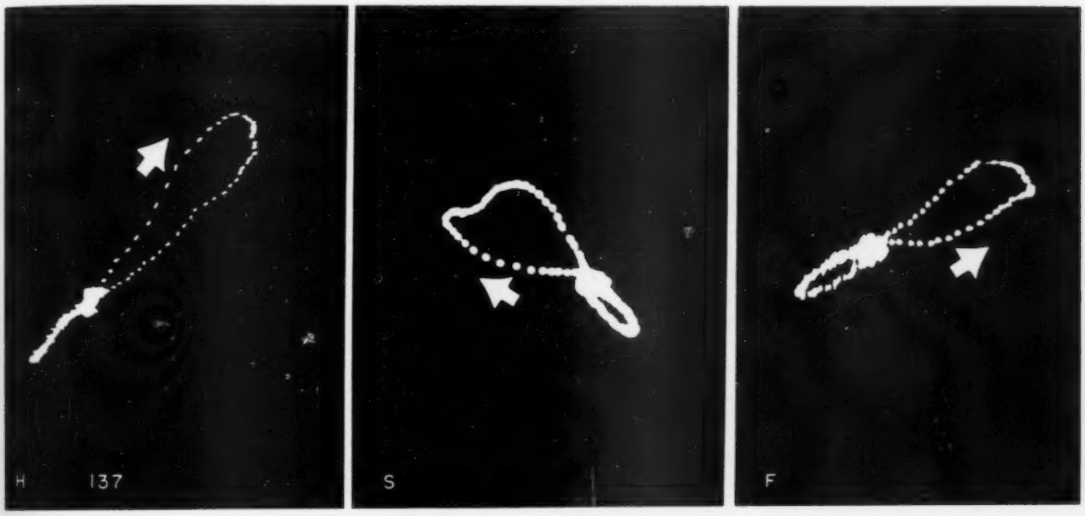

Fig. 6*A*.—Horizontal, sagittal, and frontal vectorcardiogram in left bundle branch block, Case 137 (see Fig. 5, J 137, for esophageal lead at atrial level). Note the clockwise inscription of the horizontal plane QRS sÊ loop and the contiguity of the interrupted segments in the three planes.

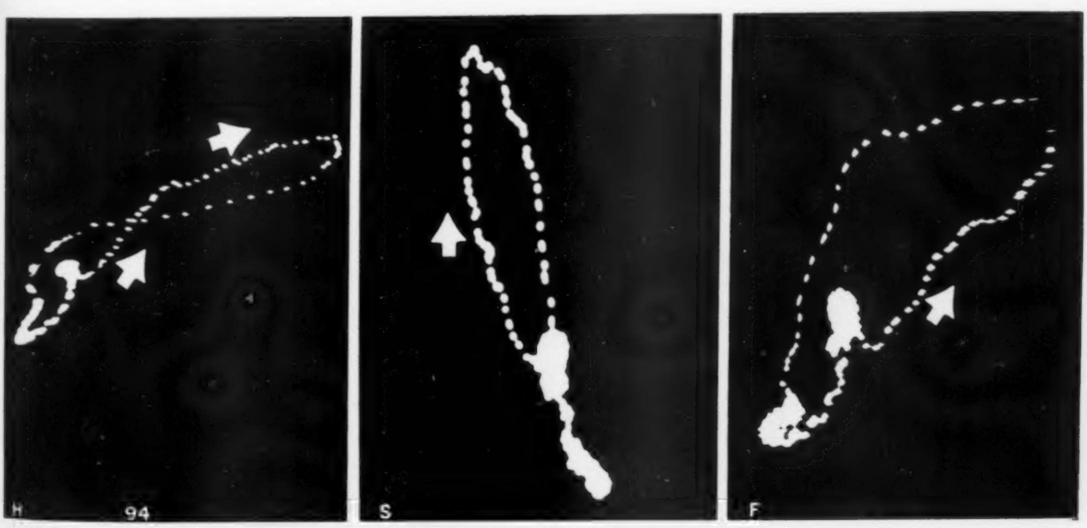

Fig. 6*B*.—Horizontal, sagittal, and frontal vectorcardiograms in left bundle branch block, Case 94 (see Fig. 5, L 94). Note the open QRS sÊ loop, indicating RS-T segment deviation.

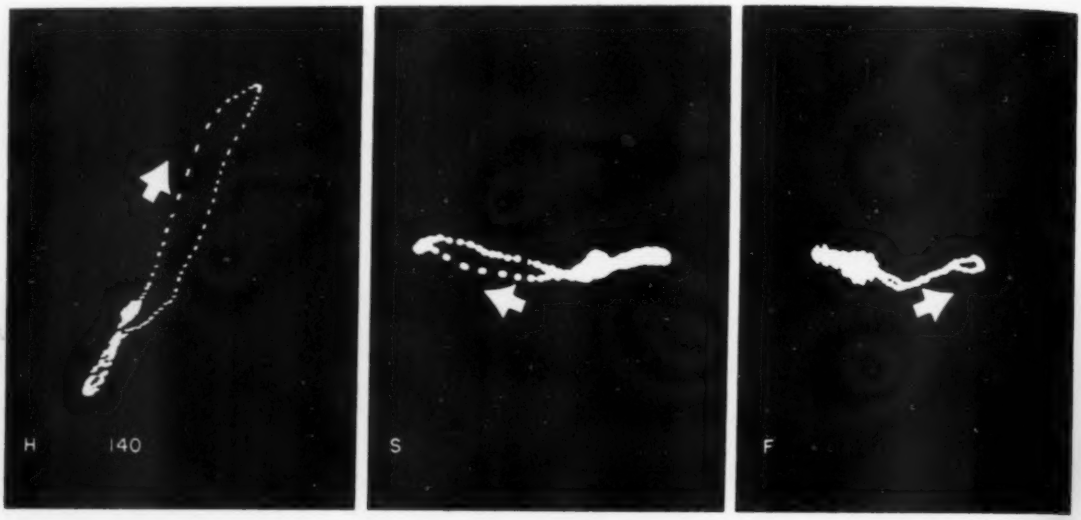

Fig. 7*A*.—Vectorcardiogram in left bundle branch block, Case 140 (see Fig. 5, F 140).

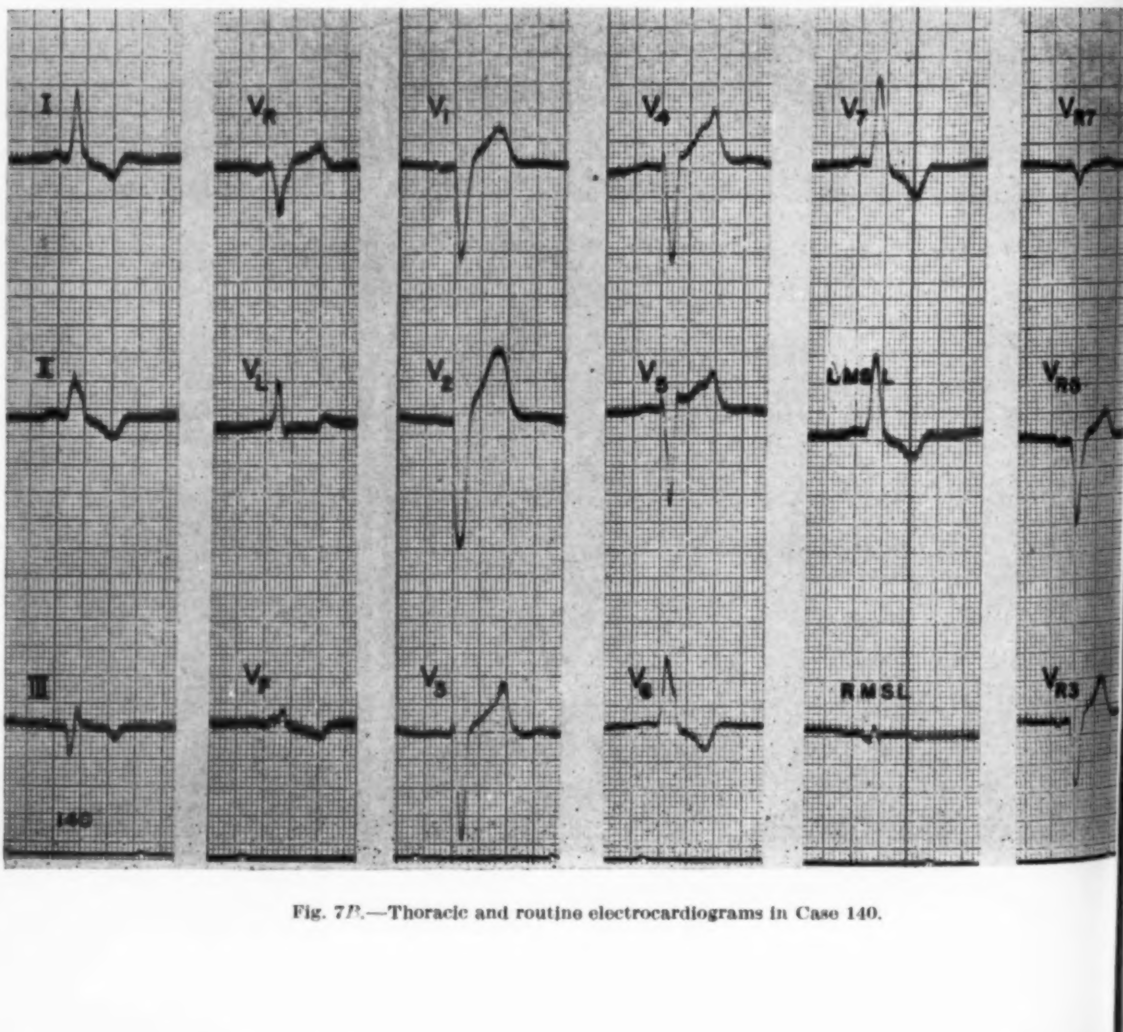

Fig. 7*B*.—Thoracic and routine electrocardiograms in Case 140.

The frontal plane QRS sÊ loops were inscribed in the I and VI sextants of the triaxial system of Bayley and in a counterclockwise direction. The terminal portion of the QRS sÊ loop was open, and the T sÊ loop was opposite in position to the QRS sÊ loop.

The sagittal plane QRS sÊ loops were inscribed upward and posteriorly and in a clockwise direction.

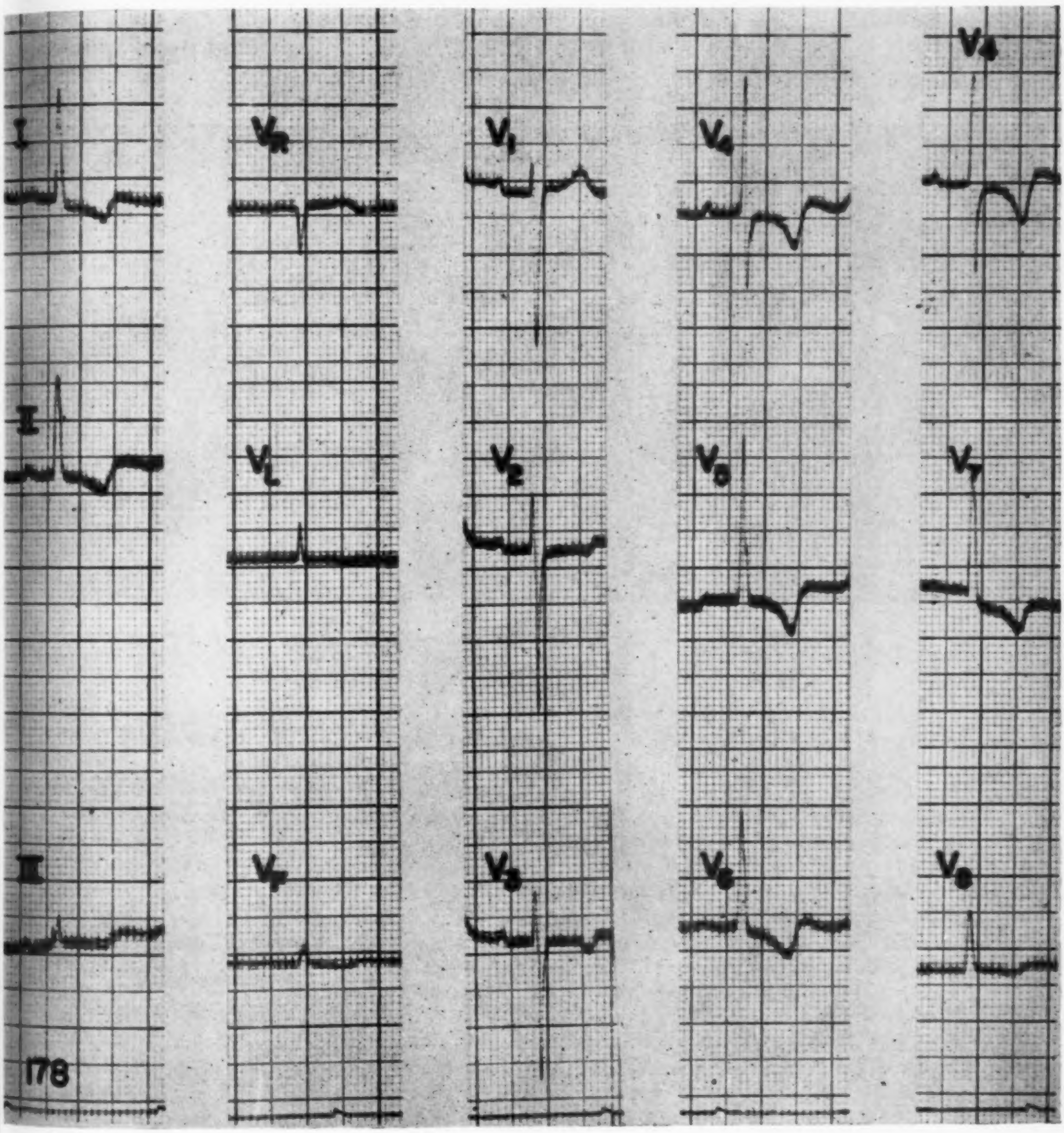

Fig. 8A.—Case 178, left ventricular hypertrophy. See text for details.

The horizontal plane QRS sÊ loops were inscribed posteriorly and to the left. The direction of inscription was clockwise. In five patients, the loop was "figure 8" in configuration with the distal portions inscribed in a clockwise direction. The T sÊ loop was essentially opposite in position to the QRS sÊ loop, and the terminal portion of the QRS sÊ loop was open.

Intermittent Left Bundle Branch Block.—Two patients with normal conduction were available for study in whom left bundle branch block could be induced by increasing the heart rate either by excitement or by inhalation of amyl nitrite. In each instance, regular sinus rhythm persisted during both normal conduction and left bundle branch block. (The esophageal studies have been reported in detail elsewhere.[19])

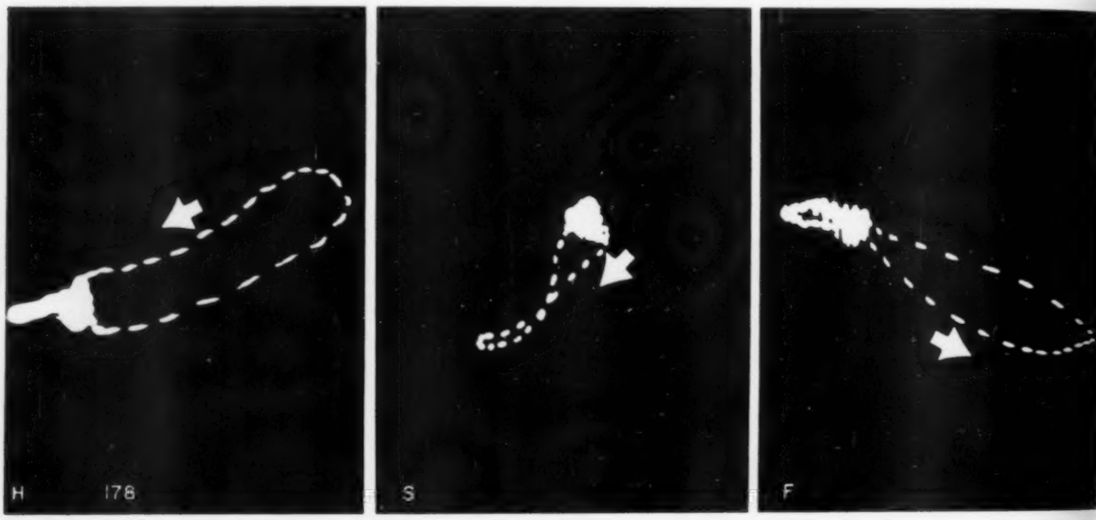

Fig. 8*B*.—Horizontal, sagittal, and frontal vectorcardiograms in Case 178.

CASE 1.—The routine electrocardiogram of M. L., a 43-year-old white woman, was essentially normal, and the QRS complex was 0.07 to 0.08 second in duration. The esophageal leads at atrial level revealed a ventricular QS pattern with an isoelectric RS-T segment. Following the inhalation of amyl nitrite, the heart rate increased, and the ventricular pattern at atrial level became RS in configuration with the RS-T segment becoming markedly depressed. The QRS complex increased in duration to 0.11 second, and the RS-T segment became depressed in the left precordial leads.

The vectorcardiograms recorded during normal conduction revealed no delay. The frontal QRS sÊ loop was inscribed in a clockwise direction and was located in the V sextant of the triaxial system of Bayley. The sagittal plane QRS sÊ loop was narrow and "figure 8" in configuration with the distal portion inscribed in a counterclockwise direction. This loop was inscribed posteriorly and downward. The horizontal QRS sÊ loop was narrow and inscribed in a counterclockwise direction posteriorly and to the left.

When left bundle branch block was present, there was definite delay in the middle and late portions of the QRS sÊ loop in each plane. The frontal plane QRS sÊ loop was inscribed in a counterclockwise direction and in the I and VI sextants. The sagittal plane QRS sÊ loop was inscribed in a clockwise direction posteriorly and upward. The horizontal plane QRS sÊ loop was narrow and inscribed in a markedly posterior direction and to the left. The terminal portion of the QRS sÊ loop remained open in each plane.

CASE 2.—The routine electrocardiogram of F. E., a 72-year-old white woman, was that of left ventricular hypertrophy (Fig. 8*A*) and was characterized by a QRS complex of increased amplitude and inverted T waves in standard leads I and II and in the left precordial leads. The QRS complex in Lead III was upright and the T wave diphasic. The duration of the QRS complex was 0.06 second. When the cardiac rate increased, the duration of the QRS complex became 0.11 second and marked left axis deviation appeared.

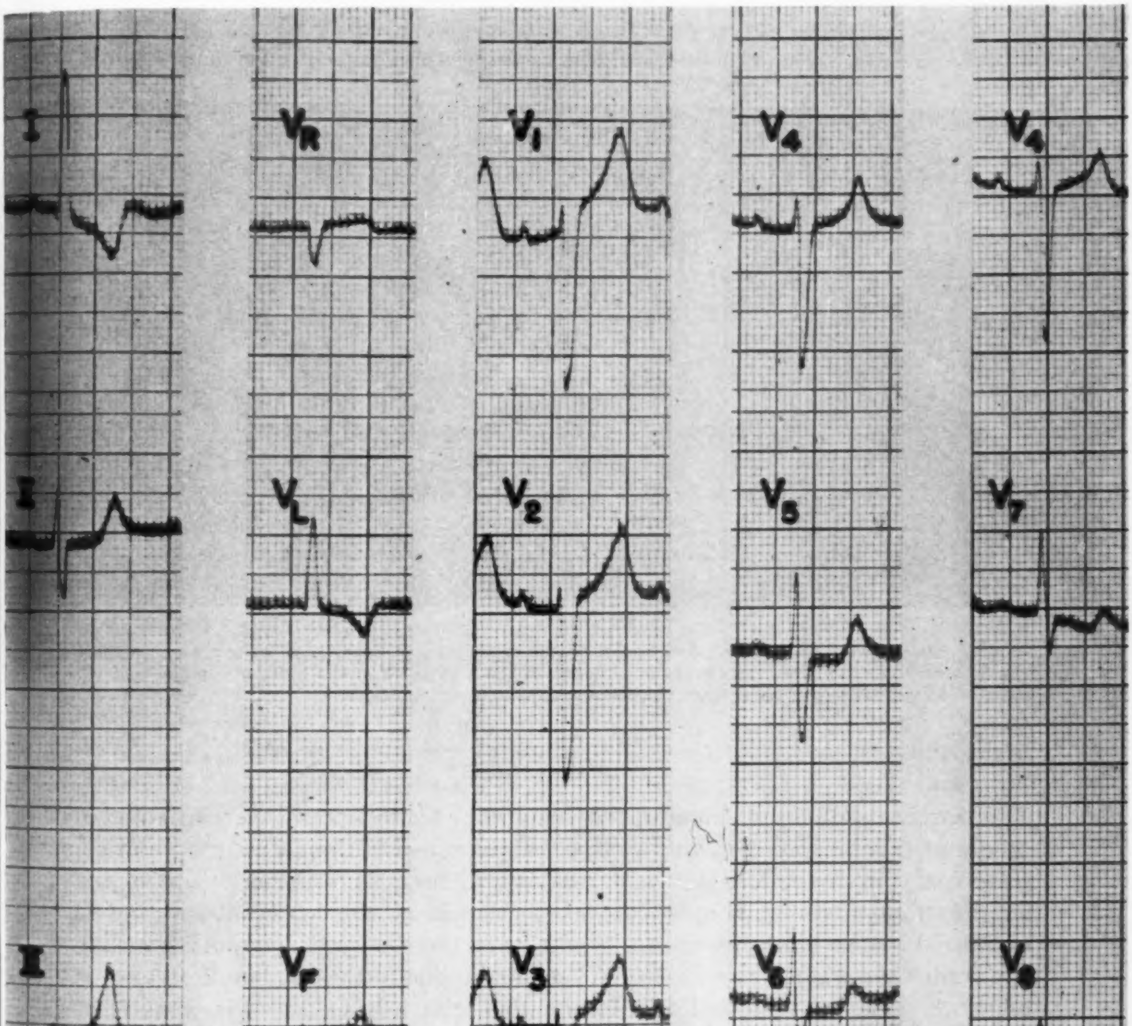

Fig. 9*A*.—Same case as Fig. 8*A* and 8*B* after appearance of left bundle branch block. Note increase in duration of the QRS complex and appearance of left axis deviation.

The vectorcardiogram recorded during normal conduction revealed no delay (Fig. 8*B*). The frontal QRS sÊ loop was inscribed in a counterclockwise direction in the VI sextant. The sagittal QRS sÊ loop was narrow and "figure 8" in configuration with the distal portion inscribed in a counterclockwise direction posteriorly and downward. The horizontal QRS sÊ loop was inscribed in a counterclockwise direction posteriorly and to the left.

When the QRS complex increased in duration (Fig. 9*A*), there was definite delay in the inscription of the middle portion of the QRS sÊ loop in each plane (Fig. 9*B*). The frontal plane QRS sÊ loop was inscribed in a counterclockwise direction in the I sextant. The sagittal plane QRS sÊ loop was inscribed posteriorly and upward in a clockwise direction. The horizontal plane QRS sÊ loop was narrow and "figure 8" in configuration with the terminal portion inscribed in a clockwise direction. The loop in the latter instance was inscribed posteriorly and to the left.

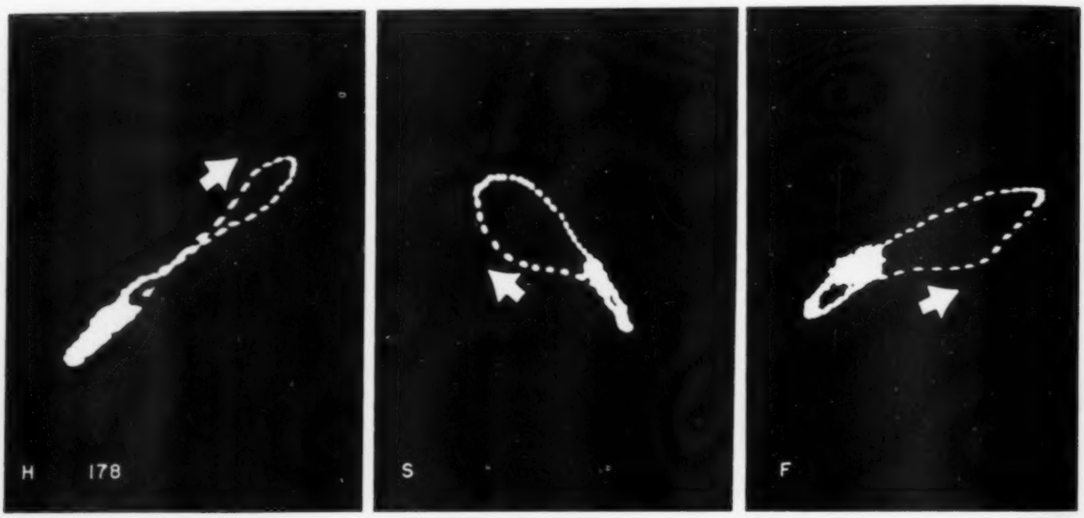

Fig. 9*B*.—Horizontal, sagittal, and frontal vectorcardiograms in Case 178 after appearance of left bundle branch block. Note the change in direction of the inscription of the horizontal plane QRS sÊ loop and the contiguity of the interrupted segments (compare with Fig. 8*B*).

DISCUSSION

During normal conduction the instantaneous resultant electrical forces produced by the spread of the wave of excitation over the entire left ventricle point away from the left ventricular cavity. This results in negativity of the left ventricular cavity throughout depolarization of the left ventricle and is evidenced by the inscription of a QS pattern in the electrocardiograms recording left ventricular cavity potentials. When conduction in the left bundle branch is markedly delayed or completely interrupted, the impulse spreads from right to left through the ventricular septum below the region of the block. As a result, early positivity is recorded in the left ventricular cavity in left bundle branch block as evidenced by an early R wave in the electrocardiograms recording left ventricular cavity potentials. The subsequent activation of the free wall of the left ventricle produces negativity in the left ventricular cavity as evidenced by the inscription of a final S wave in the electrocardiograms recording left ventricular cavity potentials. Wilson and associates and Sodi-Pallares and

associates recorded QS patterns with electrodes inside the left ventricular cavity in animals with normal conduction and an RS pattern with the electrodes inside the left ventricular cavity in animals with left bundle branch block.[3,4,5] Similar results have been obtained by catheterization of the left ventricle in human beings.[2,6]

It has also been demonstrated that esophageal electrocardiograms recorded at atrial level, as evidenced by the presence of an intrinsic atrial deflection, reflect left ventricular cavity potentials.[16,20] In left ventricular hypertrophy the electrocardiogram at this level was characterized by a QS or Qr pattern with an elevated RS-T segment.[7] In left bundle branch block the electrocardiogram at this level was characterized by an RS pattern with a markedly depressed RS-T segment.[8] In the present study, most of the patients were also studied with esophageal leads in order to distinguish more accurately between left ventricular hypertrophy and left bundle branch block. Some of the earlier studies of vectorcardiograms in these two conditions have been hindered by not employing the horizontal plane and by the apparent inclusion of cases of left ventricular hypertrophy among those of left bundle branch block and vice versa. Strict adherence to criteria based merely upon the duration of the QRS complex and the time of onset of the intrinsicoid deflection over the left precordium is not without limitations.

In the present study, the vectorcardiograms of the twenty patients with left ventricular hypertrophy were characterized by the inscription of the QRS $s\hat{E}$ loop in the frontal plane in the I or VI sextant of the triaxial system of Bayley. They were recorded in a counterclockwise direction in seventeen, while in the remaining three, the loops were narrow and "figure 8" in configuration with the distal portion inscribed in a clockwise direction. The sagittal plane QRS $s\hat{E}$ loop was inscribed in a clockwise direction and was downward and posterior in twelve, upward and posterior in six, and upward and slightly anterior in two. The horizontal QRS $s\hat{E}$ loop in each case was inscribed in a counterclockwise direction posteriorly and to the left.

In no instance of left ventricular hypertrophy was there evidence of localized or diffuse delay in the inscription of the loop. The beam of the cathode ray oscillograph recorded a QRS $s\hat{E}$ loop in which the time markings were fairly regularly spaced along the loop.

In left bundle branch block, the QRS $s\hat{E}$ loops in the frontal plane were also in the I or VI sextants and were also inscribed in a counterclockwise direction. The sagittal plane QRS $s\hat{E}$ loops, as in left ventricular hypertrophy, were inscribed in a clockwise direction but were consistently upward and posterior. In the horizontal plane, the QRS $s\hat{E}$ loops were inscribed posteriorly and to the left. However, in the horizontal plane, the direction of the inscription was clockwise in every patient with left bundle branch block as distinguished from left ventricular hypertrophy. In five patients, the loop was "figure 8" in configuration with the distal portion inscribed in a clockwise direction.

In every instance of left bundle branch block, there was distinct delay in the inscription of the QRS $s\hat{E}$ loop in each plane, usually in the mid-portion, as evidenced by the extremely close spacing of the time markings. Other

authors[12,14] utilizing spatial vectorcardiograms in the analysis of left bundle branch block, have described plateaus and thickening of the QRS sÊ loops which apparently correspond to the delay recorded by the methods employed in the present study.

The difference in the direction of the inscription of the horizontal plane QRS sÊ loop in left ventricular hypertrophy and left bundle branch block was a constant finding. Normally, the last part of the heart activated is the posterobasal aspect of the left ventricle. Hence, in normal conduction, the onset of the intrinsicoid deflection occurs earlier in left precordial leads reflecting the anterolateral aspect of the left ventricle than in simultaneously recorded esophageal leads reflecting the posterobasal aspect of the left ventricle. In left bundle branch block, however, the onset of the intrinsicoid deflection occurs later over the anterolateral aspect than over the posterobasal aspect of the left ventricle. The earlier activation of the posterobasal aspect of the left ventricle in left bundle branch block may be explained by the shorter time required for the excitation process to spread from the right side of the septum to the posterobasal aspect of the left ventricle than to the anterolateral aspect of the left ventricle.

The inscription of the horizontal plane QRS sÊ loop in a counterclockwise direction in left ventricular hypertrophy indicates that the balance of the electromotive forces is such that the vector is directed anteriorly before being directed posteriorly. Hence, the intrinsicoid deflection is recorded earlier in precordial leads than in leads over the posterobasal aspect of the left ventricle. On the other hand, the clockwise inscription of the horizontal plane QRS sÊ loop in left bundle branch block accounts for the earlier onset of the intrinsicoid deflection over the posterobasal aspect of the left ventricle than over the anterolateral aspects. These results were in accord with the findings recorded in esophageal studies of left bundle branch block in which the inscription of an RS pattern over the posterobasal aspect of the left ventricle indicates that activation of more distal areas occurs after the posterior basal aspect of the heart has been activated.[8]

The clockwise direction of inscription of the QRS sÊ loop in the horizontal plane is not specific for left bundle branch block since in right ventricular hypertrophy, myocardial infarctions, and other isolated conditions, the loop may also be inscribed in a clockwise direction. In both left bundle branch block and left ventricular hypertrophy, however, the QRS sÊ loop is inscribed posteriorly and to the left in the horizontal plane, while the loops usually occupy different quadrants in the other conditions. Hence, confusion is not apt to occur in the differentiation between these conditions and between left ventricular hypertrophy and left bundle branch block.

The T sÊ loops were usually opposite in position to the QRS sÊ loops in the horizontal plane. This is in accord with the recording of T waves opposite in direction to the QRS complex in precordial leads. The terminal portion of the QRS sÊ loop was open in those instances in which there was deviation of the RS-T segment. A more detailed analysis of the T waves and RS-T segments in vectorcardiograms is now being made.

The two cases of intermittent left bundle branch block described in the present report also indicated the differences in the vectorcardiograms of left bundle branch block which is probably incomplete as compared to left ventricular hypertrophy. In Case 2, whenever the QRS complexes increased in duration and were altered in configuration, the direction of rotation of the QRS sÊ loop in the horizontal plane changed from counterclockwise to clockwise, and delay appeared in the inscription of the loop. Other investigators[13] have reported reversal of direction in the frontal plane in a case of transient left bundle branch block. The QRS complexes of increased duration would usually be interpreted as representing some degree of interventricular block in comparison to the QRS complexes of left ventricular hypertrophy routinely recorded in this patient. The spatial vectorcardiogram, however, clearly demonstrated that the widened QRS complexes were those of left bundle branch block, probably incomplete, rather than of a more marked left ventricular hypertrophy pattern.

In Case 1, the esophageal records had revealed increasing positivity in esophageal leads recorded at left atrial levels, thus demonstrating increased degrees of left bundle branch block.[19] An electrokymogram revealed an increase in the difference between the earlier systolic rise of the pulmonary artery curve as compared to that of the carotid pulse curve of from 0.03 second during normal conduction to 0.05 to 0.06 second during left bundle branch block. This would indicate a delay of 0.02 to 0.03 second during the conduction delay.* The vectorcardiogram demonstrated delay in the inscription of the QRS sÊ loop and reversal in the direction of the inscription of the loop in the horizontal and frontal planes when left bundle branch block supervened. Thus, in both of these patients, the appearance of delay and the reversal in the direction of inscription of the loop coincided with the appearance of left bundle branch block.

It should be noted that the direction of inscription of very narrow loops may vary with respiration. The utilization of the horizontal plane is especially important since it is from this plane that the precordial leads may be analyzed.[21] The interpretation of the QRS sÊ loop may lead to considerable error if recorded in any one plane. The simultaneous recording of all three planes (frontal, sagittal, and horizontal) permits the greatest facility in spatial orientation, obviating the need for stereoscopic projection[12] or the construction of wire models.[14,15] The Duchosal-Sulzer[14] technique, as employed in the present study, is especially valuable for the recording of the QRS sÊ loop in the horizontal plane.

Some investigators have suggested that the pattern of the loops in left bundle branch block can be used to distinguish diffuse myocardial damage from a local lesion as the cause of left bundle branch block. Pathological reports are often of little value in such a controversy as many studies have indicated.[22,23] It is not likely that gross diffuse damage to the left bundle branch would give a different pattern from local damage, since both would result in a similar electrophysiological state, i.e., delayed activation of the left ventricle. The two cases of intermittent left bundle branch block presented in this report can be explained upon the basis that there was functional impairment of the left bundle branch so

*The electrokymographic study was performed by Dr. Simon Dack and Dr. David H. Paley, New York, N. Y.

that the left ventricle was activated from right to left. The further information as to whether such an impairment is localized or diffuse is not available from vectorial analysis of the ventricular complex alone.

The QRS sÊ loop as recorded by the cathode ray oscillograph represents the advancement of the terminus of an instantaneous vector during the time consumed by the spread of the wave of accession. The vector at any one instant is the resultant of many diverse electromotive forces which vary in direction and magnitude.[11,12,17,18,24] In left bundle branch block, there is delay in the spread of the wave of accession in the left ventricle due to the defect in the left bundle branch.[25] This delay is apparent from the direction of and the delay in the inscription of the loop and its position in space.

The delay in the inscription of the QRS sÊ loop in left bundle branch block corresponds to the notching or slurring in unipolar leads recorded over the left precordium. The initial part of the QRS sÊ loop in left bundle branch block represents normal activation of the right ventricle unopposed by electromotive forces arising in the left ventricle. The delay probably reflects muscular conduction in the septum as the impulse spreads from right to left. The latter part of the QRS sÊ loop represents activation of the left ventricle after the impulse has reached the left bundle branch below the region of the block. The latter part of the loop is attributed to unopposed potentials arising from the left ventricle which is activated after the main portion of the right ventricle has been activated. Hence, the QRS sÊ loop in left bundle branch block is inscribed to the left as contrasted to that in right bundle branch block.[12] The vectorcardiogram clearly demonstrates the delay and spatial orientation of the QRS sÊ loops in each plane and thus allows the differentiation of left ventricular hypertrophy from left bundle branch block.

SUMMARY

1. Simultaneously recorded frontal, sagittal, and horizontal plane vectorcardiograms are described in twenty patients with left ventricular hyerptrophy, fourteen patients with left bundle branch block, and two patients with intermittent left bundle branch block.

2. In left ventricular hypertrophy, the QRS sÊ loops in the frontal plane were usually inscribed in a counterclockwise direction in the I and VI sextants; in the sagittal plane, in a clockwise direction and posteriorly; in the horizontal plane, in a counterclockwise direction posteriorly and to the left.

3. In left bundle branch block, the QRS sÊ loops in the frontal plane were inscribed in the I and VI sextants in a counterclockwise direction; in the sagittal plane, in a clockwise direction posteriorly and upward; in the horizontal plane, in a clockwise direction posteriorly and to the left.

4. There was no delay in the inscription of the QRS sÊ loop in left ventricular hypertrophy while there was definite delay in left bundle branch block.

5. The significance of these findings is discussed.

We wish to express our appreciation to Miss Thelma M. Shafran for technical assistance.

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INNERVATION OF THE DOG'S HEART

K. T. Tcheng, M.B.*

Chungking, China

THE present paper is a continuation of previous publications. In one of them,[41e] the important investigations concerning the innervation of the heart were outlined in its bibliography. Although this question has been studied by many histologists, more exact results could be obtained with an improved technique. As dogs' hearts are frequently used in the physiological experiments, it might be of some value to describe the observations on this animal.

MATERIAL AND TECHNIQUE

Two 3-day-old puppies were sacrificed for this study. The hearts were perfused under fresh condition with the fixator S.W.24† directly into the two ventricular cavities; the animals had been anesthetized with chloroform. The hearts were then impregnated in toto, following the method of Weber.[42] Serial sections which had been cut horizontally, 10 microns thick, were mounted on large slides 16 cm. by 3.5 cm. in size. One can mount sixteen sections or more on each one of such slides. It is more convenient to use them for studying the serial preparations by following their topographical relations; much less time will be spent than in using the ordinary ones.

THE CARDIAC GANGLIA

After the discovery of Bidder, Ludwig, and Remak of the existence of cardiac ganglia in the heart of different vertebrates, this matter was studied by many authors (Berkley,[5] Jacques,[19] Dogiel,[11] Smirnow,[37] Michailow,[29] Fahr,[12] Meiklejohn,[28] Perman,[33] Woollard,[43] Glomset and Glomset,[15] Conti,[9] and others). The most interesting demonstrations were given by Fahr,[12] who reconstructed the heart of a 10-day-old child by mapping the distribution of the cardiac ganglia; by Meiklejohn,[28b] who showed the topography of the cardiac ganglia of a rat's heart by drawing them one section out of twenty; and by the present author, who reconstructed the interauricular and interventricular septa of the heart of the lamb on superposed glass plaques showing the relation between the cardiac ganglia and the auriculoventricular node and the common trunk of the bundle of His.[41f]

Concerning the distribution of the cardiac ganglia in the heart of the dog, the present observations were mainly like those of Woollard.[43] These ganglia were found in the subepicardial tissue around the left and particularly the right

From the Department of Histopathology, Instituto Nacional de Cardiologia de Mexico, Mexico, D. F., Mexico.

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*Research Fellow in the Instituto Nacional de Cardiologia de Mexico.

†(a) Dioxane, 50 c.c.; isopropyl alcohol, 25 c.c.; commercial Formalin, 15 c.c.; formic acid, 2 c.c.; chloral hydrate, 10 Gm.; cobalt nitrate, 1 Gm. and (b) physiological saline. The solution is made by mixing an equal volume of (a) and (b) with the addition of 5 per cent of glacial acetic acid.

auricles in their anterior, lateral, and posterior aspects, between the aorta and the pulmonary artery, in the interauricular septum, and around the sinoauricular and auriculoventricular nodes. But one observation which was contrary to the statements of Woollard as well as to the majority of authors was the presence of intramural ganglia. In the right ventricle of one puppy, in some preparations, six ganglia were even found buried in the depth of the myocardium. Fig. 1 is the photomicrograph of one of these ganglia. The morphology and the relationship with the nerve fibers exclude the confusion with connective tissue cells. The topography of this ganglion was followed in forty-four continuous serial sections; that is, its length was 0.44 mm. It was first found to be situated superficially on the surface of the ventricular myocardium and to be somewhat oval in shape; then it penetrated into the depth of the myocardium, becoming more elongated, and finally divided intramurally into two groups. In these slides the author found two cells as a minimum and fifty cells as a maximum in one section. These ganglia have only been found in the basal part of the right ventricle, never in the apex. It was possible to follow the nerve fibers that have a connection with other intramural ganglia.

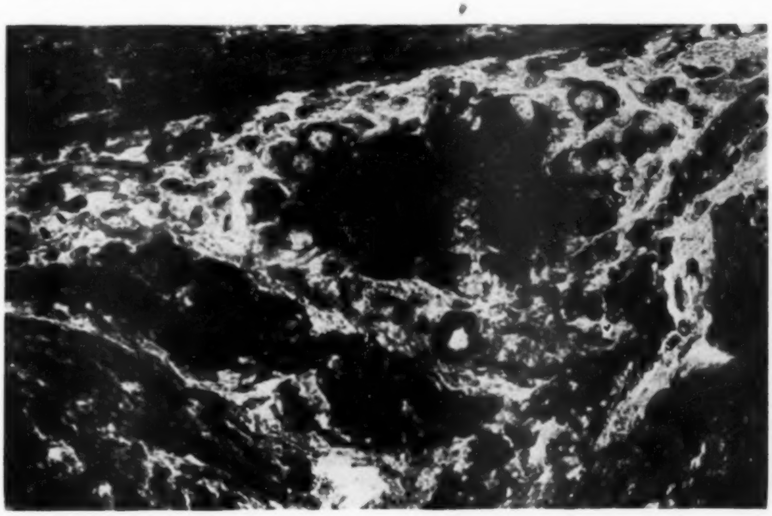

Fig. 1.—A nerve ganglion situated in the depth of the myocardium of the right ventricle (photomicrograph ×500).

Kent[23] had found connections between the auricles and the ventricles other than the bundle of His. Keith and Flack[22] described the "apposition" of the auricular and the ventricular muscles in the right lateral auriculoventricular region in the hearts of the rat and the sparrow. They had not observed such a direct union as described by Kent. The author found a similar apposition in the heart of the puppy. Some muscular fibers united the right lateral auricular and ventricular myocardium, although they were not abundant. In this region, there were also some buried ganglia which could be followed and were continuous with the superficial ganglia in the auriculoventricular sulcus.

Single nerve cells along the gross nerve trunks at the base of the heart were occasionally found.

THE MOTOR INNERVATION OF THE MYOCARDIUM

In previous work, the author had noticed that the double innervation of the heart was still a subject of dispute among histologists (Woollard,[43] Boeke,[7] Fattorusso,[13] Nonidez,[31] Kaylor,[21] Landau,[24] and others). Some additional observations obtained from the study of the heart of the puppy are offered. The myocardium of the auricles, as well as of the ventricles, was doubly innervated by excitatory and inhibitory fibers, although the latter were more scarce in the ventricles than the former. This result is similar to that found in the heart of the cat.[41c] The nerves, which are composed of postganglionic sympathetic and parasympathetic fibers (and some sensitory fibers), form a subepicardial plexus and descend along the cephalocaudal axis of the heart. The sympathetic postganglionic fibers are derived from the ganglia of the sympathetic chain, while the

Fig. 2.—A nerve which is composed mainly of sympathetic and a few parasympathetic fibers penetrates into the apical myocardium from the subepicardial plexus (photomicrograph ×800).

parasympathetic postganglionic axones are those of the intrinsic cardiac ganglia which receive the impulse from the vagal preganglionic fibers. These nerve bundles accompany the coronary arteries. They penetrate into the myocardium at different levels. It is worthy of note that an abundant number of nerve fibers penetrates into the apex. Fig. 2 shows one of the nerve bundles in the apical region. It is composed mainly of excitatory fibers and a few inhibitory ones. This is of particular interest in connection with the results of electrocardiographic research. Investigations with the electrocardiogram have shown that the apex of the heart is one of the first activated regions in the free wall of the left ventricle.[38] Although cardiac excitation is thus explained as being of myogenic origin, the particular abundance of nerve fibers in that region lends a certain weight to the view of automatism through the influence of the nervous impulses.

The author found that in the higher segments of both ventricles, as in the apex, the parasympathetic fibers were more scarce than the sympathetic postganglionic fibers. Jourdan and Froment[20] produced a more or less notable slowing of the idioventricular rhythm by the electrical stimulation of the pneumogastric nerves in the neck after they had crushed the bundle of His of the heart of the dog. The author's observations give an anatomical proof for their suggestion of the existence of vagal fibers in the ventricles; this existence was doubted by Nonidez[31] who failed to demonstrate them in his preparations.

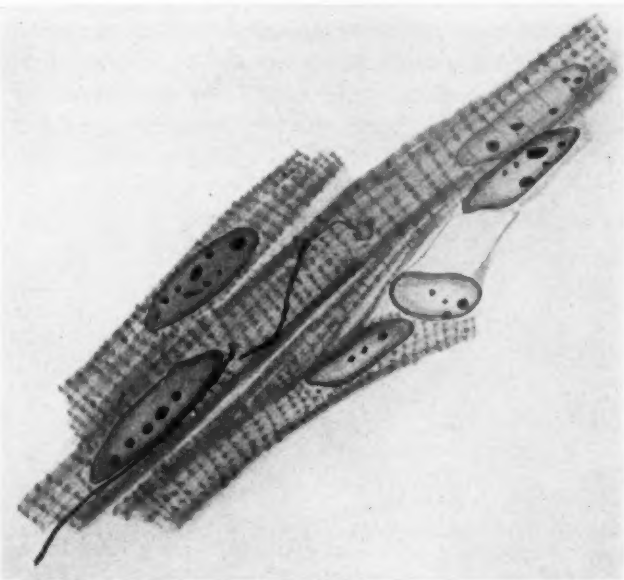

Fig. 3.* A parasympathetic fiber found in the left ventricle ends in a fine metaterminal apparatus of Weber, represented by a very fine filament attached by a few granules (×2,300).

Boeke,[7] Fattorusso,[13] and Landau[24] created a number of terms: "ground sympathetic plexus," "periterminal network," and "cordon plasmatique nucléé" which have been regarded by many authors as artifacts, due partly to a malfixation resulting from the agglutination of the free but closely situated fibers and partly to a misinterpretation of the nonnervous argyrophilic reticulum (Fedorow and Matwejewa,[14] Nageotte,[30] Nonidez,[31] Weber,[42] and Tcheng[41]). Since the use of the method of Bielschowsky in studying the autonomic nervous system, a "reticular theory" has developed. Two leading proponents are Boeke[7] and Stöhr.[39] According to them, the interneuronal or neuroeffector synapses are anastomosed in a syncytium. By Stöhr it is called "Nervöses Terminalreticulum." However, there are still some arguments between Boeke and Stöhr as to the matter of degree of artifacts.

The ring form endings which had been drawn by Boeke[7] in the heart of the tortoise and by Nonidez[31] in the dog's heart were frequently found in the author's preparations. But the finest structure, the metaterminal apparatus, has not been demonstrated by methods other than Weber's technique.[42] Different forms of

*All the drawings were made with the aid of camera lucida.

their endings have been shown in previous papers. Only two figures are added in this article. Fig. 3 shows a parasympathetic fiber found in the left ventricle, which ended in a fine metaterminal filament attached by a few granules. This reticulated form had been observed by Denber[10] in man and also in the hearts of other mammals. Fig. 4 reproduces a sympathetic fiber which penetrated perpendicularly through the myolemma into the interior of a muscular cell in transverse section and ended in a small granule touching the nuclear surface. The intracellular situation of this terminal portion is clearly seen. The intraprotoplasmic situation of a nerve fiber in the myocardial cell was a question that arose among the histologists after the suggestion of its presence by Ranvier.[34] The present preparations demonstrated them in the interior of the muscle cells in different sections, longitudinal, tangential, and transverse; in all cases, the point of penetration was precisely observed. Its significance has already been considered in previous publications[41] and does not require further repetition.

Fig. 4.—Sympathetic fiber which penetrates perpendicularly through the myolemma into the interior of the muscular cell which is cut in the transverse section and ends in a small granule touching the nuclear surface (×2,300).

Meiklejohn[28a] showed, with Cajal's method, a nerve fiber forming a spiral around a group of nuclei in the sinoauricular node of a monkey. This formation has not been reproduced by Nonidez in the same region of the same animal, nor has it been found in any part of the different mammals the author has studied. Only once has the author seen a similar picture in the preparation of a young puppy with an ocular ×5 and with an oil immersion objective. (Meiklejohn demonstrated this picture with an ocular ×4.) The change to an ocular ×10, for routine examinations, showed that the formation was composed of several fragments of nerve fibers in tangential section together with some Schwann cells. It was more clearly identified with an ocular ×15. In order to rule out the possibility that it might be a tangential cut of a spiral termination, its topography was followed in ten continuous serial sections (five above and five below). The continuation with longer fibers convinced the author that it was not an end formation. The spirals around groups of nuclei as well as other forms resembling the motor endplate are probably not nerve endings in the heart.

THE SENSITORY INNERVATION OF THE MYOCARDIUM

The sensitory fibers in the myocardium have already been described by many authors (Smirnow,[37] Heymans and Demoor,[17] Schmidt,[36] and Dogiel[11]). This

question has been recently studied with more advanced techniques (Woollard,[43] Lawrentjew,[25b] Nonidez,[31] and Pannier[32]). Woollard noticed that the sensitory fibers were present in the subpericardial and endocardial noncontracting connective tissue. Nonidez, who did not find the sensitory fibers in the auricles, explained the Bainbridge reflex as being transmitted solely by the arborizing fibers in the vena cava. It was Pannier who found the sensitory fibers in the myocardium of the auricles with a criterion of certainty. The diversity of opinion among the histologists about the presence of sensitory fibers depends upon the recognition of their morphological characteristics. The most specially defined sign is the arborization of the nerve fibers. This characteristic is important, but it is not the only criterion. Sensitory fibers can be diagnosed by their caliber and

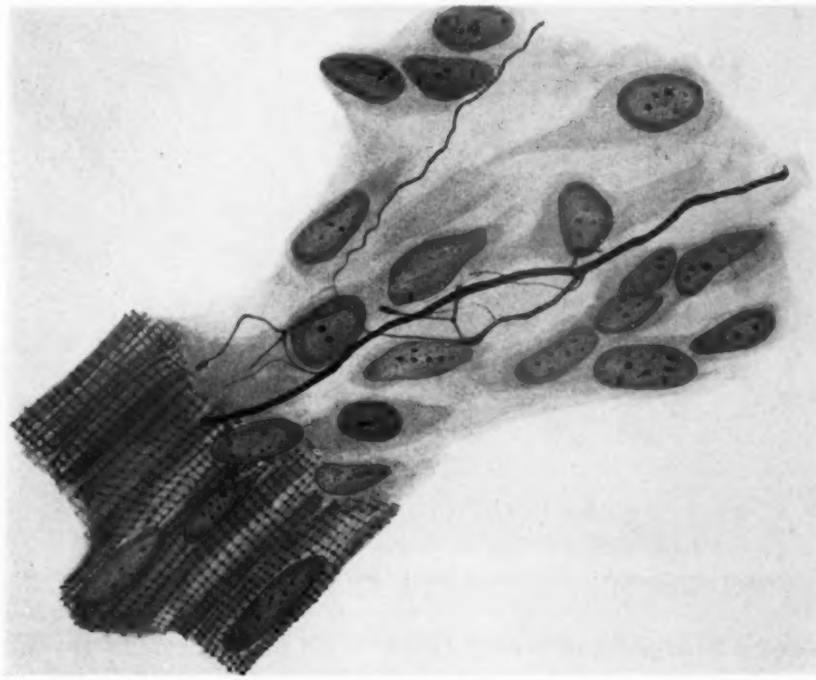

Fig. 5.—Sensitory fiber of the arborization type in the endocardial tissue of the right auricle. It divides into branches which end in reticular or ring forms of terminations (×1,700).

tint in most instances. The gross and deeply impregnated fibers degenerate after vagotomy (Lawrentjew[25b] and Tcheng[41d]). Also similar sensory fibers have been found in other organs, such as the lungs and pleura (Baumann[4a]), the suprarenal capsules (Denber[10]), and the dura mater (Weber[42c]). It is of particular interest that the sensitory fibers defined in Weber's laboratory have been recently found in the temporomaxillary chondroid tissue of the embryo of the guinea pig by Baumann.[4b] This author expressed his opinion that this finding can be regarded as an anatomical basis to explain the "knockout" in boxing. As concerns the sensitory innervation of the dog's auricles, the author has found them in considerable numbers in the depth of the myocardium as well as in the

subendocardial connective tissue. Most of the sensitory fibers possess a similar morphology to those observed in other parts of the heart that have already been described in the cat. Their common ending is represented by several granules united by fine filaments.[41e] The arborization type of sensory fibers has also been found. Fig. 5 shows a thick and black sensitory fiber which left the auricular myocardium, passing into the endocardial connective tissue. It divided into arborizations which ended in reticular or ring forms of terminations. (It is of value to mention that there are more sensitory fibers in the right auricle than in the left, while they are rarely found in the ventricles.) The author had the same

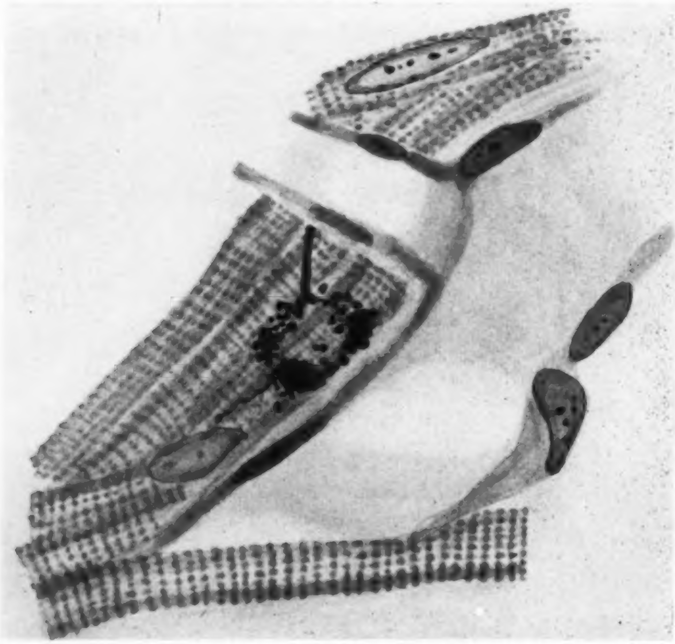

Fig. 6.—Sensitory termination in the form of "grappe de raisin" is found in the left ventricle (×2,300).

experience in studying the sensitory innervation of the heart of the cat. Fig. 6 shows a sensory nerve ending in the form of "grappe de raisin," as it had been found in the node of Tawara of the lamb.[41b] It seems this termination has a close relationship with a capillary. Whether it transmits the sensibility of this part of the ventricular muscle or of this coronary capillary is very difficult to judge. However, the sensory fibers and endings in the ventricles are much less significant than those in the auricles in regard to the scantiness of their number in the former. These observations led to the conclusion that there is an anatomical basis to support the theory of the Bainbridge and McDowall reflexes, initiated by the afferent nerve fibers in the auricles, particularly the right one.

THE INNERVATION OF THE AURICULOVENTRICULAR SYSTEM OF HIS-TAWARA

Although the auriculoventricular system of His of the dog's heart has no identical morphology with that of the sheep and the ox, its difference from the ordinary myocardium can be recognized. The auriculoventricular node of

Tawara was composed of dense and interlacing finer muscular fibers. They were paler than the ordinary myocardium and with less distinct striations. In its cephalic portion, the node was united with the muscle of the auricles, while in its caudal portion, it was fused with the left ventricle dorsally and the common trunk ventrally. The cells of the common trunk and its two main branches and their ramifications were larger but still paler than the ordinary myocardium. The distinction could easily be seen, even with the silver impregnation technique which was not intended for demonstrating this system. With serial section preparations, one could easily follow the topography with certainty. The author's observations were mainly in accord with those of Tawara,[40] Lewis,[26] and Nonidez.[31]

Fig. 7.

Fig. 8.

Fig. 7.—The common trunk of the bundle of His which occupies the center of this photomicrograph is composed of paler and larger muscular cells of the Purkinje type; ventrally to it lies the muscle of the interventricular septum and dorsally the myocardium of the left ventricle (photomicrograph ×55).

Fig. 8.—Twelve sections more caudally to the previous figure, the two main branches (*L. B.* = left branch; *R. B.* = right branch) are very clearly differentiated from the ordinary myocardium. The transitions of the common trunk bifurcating into two branches are seen in the continuous serial sections between these two slides (photomicrograph ×55).

Recently, Glomset and Glomset[16] denied the existence of the bundle of His, but the author's preparations demonstrated this system both in the human and in canine hearts. Two photomicrographs showing the distinction between the ordinary myocardium and the common trunk, as well as the two main branches at two different levels, are added, even though this is not the main subject dealt with in this paper (Figs. 7 and 8).

The innervation of the auriculoventricular system of the dog's heart is quite interesting: the node of Tawara received a rich innervation, while the common trunk and the two main branches were free of nerve fibers. Nonidez[31] had only observed a large number of parasympathetic fibers in the node. He was not able to demonstrate its sympathetic innervation, nor did he find the perinodal ganglia.

The author found a richer sympathetic innervation than the parasympathetic one. Perinodal ganglia as well as single nerve cells in the nodal tissue were found in the preparations, although not abundantly. Their terminations, including intraprotoplasmic endings such as were described in the node of Tawara of the lamb, were also found in the dog.

A considerable number of sensitory fibers other than the motor fibers were also seen. Although Nonidez[31] had observed them, he did not consider their afferent nature. For him, the only criterion was arborization of thick fibers. As the author has already mentioned, he recognized their sensitory nature in view of their tint and caliber. In the study of the innervation of the auriculoventricular node of the lamb, the experiments proved this criterion, namely, the gross and black fibers degenerate after vagotomy. Furthermore, the arborization type of sensitory fibers, as shown by Nonidez in the sinoauricular node, was also found in the preparations.

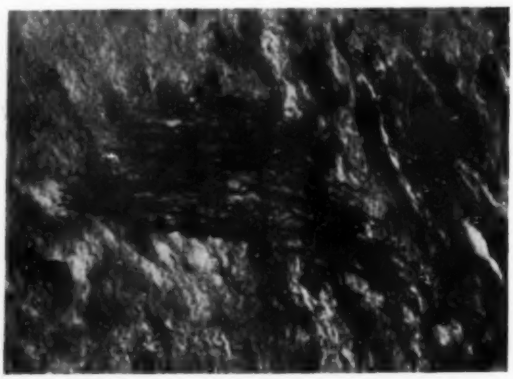

Fig. 9.—A bundle of nerve fibers in the perinodal connective tissue passing into the node of Tawara is composed mainly of sympathetic fibers and a smaller number of vagal ones. A few sensitory fibers are also seen in this bundle (photomicrograph ×800).

Fig. 9 represents a bundle of nerve fibers in the perinodal connective tissue. The bundle was followed and seen to enter the node in its next slides. This nerve was composed mainly of the finest and most faintly colored fibers (sympathetic) and a smaller number of fine and black fibers (parasympathetic). A few gross and deeply impregnated fibers which were considered to be afferent in nature were also seen in this bundle in the photomicrograph. The preparation was much clearer than this image because the undulations of the nerve fibers in different plans make the photomicrographical reproduction of high magnification quite difficult.

The author does not emphasize the cytological structure of the nodal tissue because in the strictly serial sections it was seen that the connections between the node and the common trunk were composed not only of "specialized" fibers, but also of some ordinary myocardium. Even a part of the muscular fibers in the node of this animal could not be distinguished from the ordinary myocardium. But from the neurohistological point of view, the auriculoventricular node, an

important region which unites the auricles and the ventricles, must be considered as a special area. Because it is innervated not only by an abundant number of sympathetic and parasympathetic postganglionic fibers, but also by a considerable quantity of sensitory fibers, one is then inclined to believe that this auriculo-ventricular connection might serve as a certain center of reflex. At least it was true in the two mammals that were studied, the sheep and the dog. A series of physiological researches was done on the efferent nervous control of the node of Tawara (Rothberger and Winterberg,[35] Cohn,[8] Bachmann,[1] and Jourdan and Froment[20]), but the centripetal action initiated from this region requires further investigation.

In the ventricles, the Purkinje cells were found to be situated subendocardially only and not in the depth of the myocardium. Sometimes, groups of these cells were seen in the myocardium but in following the topography the invaginated endothelium was found in the neighboring slides. As concerns the innervation of the subendocardial Purkinje cells in the ventricles, Nonidez noticed the absence of nerve fibers, but in the author's preparations, small nerve bundles in close relation with the Purkinje fibers were occasionally observed (Fig. 10), although he was not able to follow them to their anatomical neuromuscular synapses.

Fig. 10.—A few autonomic nerve fibers beneath the endothelium are in close relation to the subendocardial Purkinje cells of the left ventricle (photomicrograph x800).

SUMMARY

The observations about the innervation of the dog's heart obtained by means of Weber's silver impregnation technique can be summarized as follows:

1. The cardiac ganglia were found mainly at the base of the heart, but intramural ganglia in the depth of the right ventricle were also present.

2. There were sympathetic and parasympathetic fibers in the auricles as well as in the ventricles. In the latter, the inhibitory fibers were fewer than the excitatory ones. An abundant number of efferent nerve fibers was found in the apex.

3. Different forms of nerve endings were observed and discussed. Intraprotoplasmic terminations in the interior of the myocardial cells were undoubtedly present.

4. Sensitory nerve fibers and their terminations were found mainly in the auricles, rarely in the ventricles.

5. The auriculoventricular node of the dog's heart was not only innervated by many excitatory and inhibitory fibers, but also by a considerable number of sensitory ones. The author suggests that from the neurohistological point of view this node is a certain center of reflex.

6. The common trunk, its two main branches, and their ramifications in the interventricular septum were not innervated, but some autonomic fibers in close neighborhood with the subendothelial Purkinje cells were demonstrated in the preparations.

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THE HEART IN DYSTROPHIA MYOTONICA

CHARLES FISCH, M.D.*

INDIANAPOLIS, IND.

DYSTROPHIA myotonica (myotonica atrophica, Steinert's disease) is a familial disorder of the muscles characterized primarily by slow relaxation after contraction (myotonia) and atrophy. It differs from Thomsen's disease, or myotonia congenita, by the presence of atrophy instead of hypertrophy. The two entities were separated in 1909 by Steinert[1] and Batten and Gibb[2]. The myotonia is most pronounced in the muscles of the hand and forearm, although other groups may become involved. This symptom is in many instances overshadowed by the relentlessly progressing and more bothersome muscular atrophy. The latter assumes a more or less constant and fairly characteristic pattern. The atrophy of temporal muscles, orbicularis oris and oculi, results in so-called "myopathic facies" with an expressionless appearance of the face. The sternocleidomastoids are nearly always atrophied and may be reduced to a strand of fibrous tissue. Involvement of the pharyngeal group of muscles accounts for the low-pitched, monotonous, nasal voice with poor enunciation. Other muscle groups usually involved include the forearm, quadriceps, and dorsiflexors of the foot, although any or all muscles may become atrophied. As atrophy progresses, tendon reflexes may disappear, but the sensorium remains intact. The extramuscular symptoms and findings, namely the presence of cataracts, baldness, testicular atrophy, and various endocrine disorders, were emphasized by Fleischer[3] and Curschmann.[4] Griffith[5] was the first to focus attention on the heart. In 1911, he described a 48-year-old man with a pulse which was "usually infrequent . . . . often below 50 and on some occasions fell to 40 . . . . and sometimes as low as 36." However, at no time was there any degree of heart block. Extrasystoles were frequent during the period of observation, but the bradycardia was independent of the extrasystoles. The theory that dystrophia myotonica is a generalized disease and that changes in the muscles are only a part of the entire picture has many proponents. This concept was presented in detail and supported by an excellent review of the literature by Maas and Patterson[6] in a paper published in 1947. However, due to the nature of the disorder, patients with dystrophia myotonica are usually seen by the neurologist, and as a result the extra muscular changes have not received the attention they deserve.

The author's interest in this problem was stimulated by having the opportunity to examine six patients suffering from dystrophia myotonica, five of whom exhibited evidence suggesting heart involvement. Reviewing the status of the

From the Department of Medicine, Veterans Administration Hospital, Indianapolis.

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*Present address: Indianapolis General Hospital.

heart in this disorder, one is impressed with the paucity of reports in the English literature regarding this aspect of the disease. Consequently, it was thought worthwhile to report these cases and present as complete a review of the literature dealing with the heart in dystrophia myotonica as the available references would permit. Only reports in which electrocardiographic data and/or anatomical or roentgenographic studies of the heart were available are included in this study.

CASE REPORTS

CASE 1.—W. D., a 52-year-old white man, was admitted to the Veterans Administration Hospital on Sept. 7, 1949, complaining of "fluttering" of the heart and muscular weakness. The patient first noticed progressive weakness about eight years prior to admission. About the same time the voice became nasal in quality, and he also became aware of progressive muscular wasting.

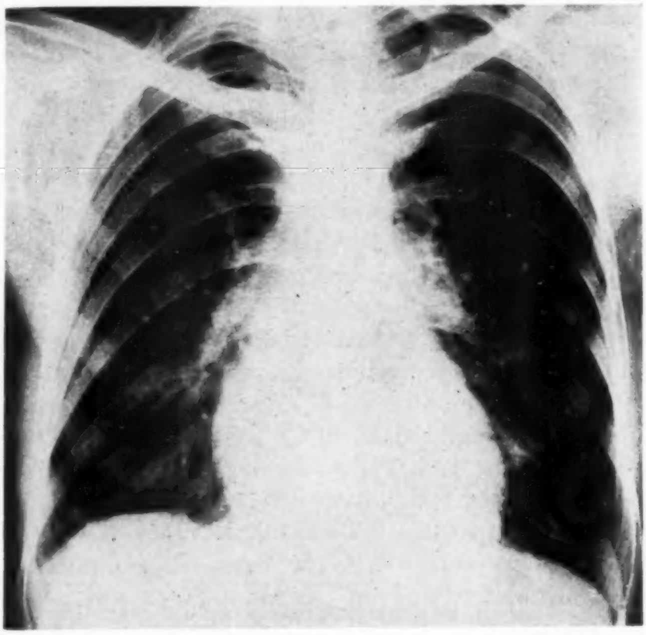

Fig. 1 (Case 1).—The roentgenogram of the chest shows moderate, generalized enlargement of the heart with exaggeration of bronchovascular markings bilaterally.

He was hospitalized in another institution in 1946, where he was studied rather extensively with a resultant diagnosis of Addison's disease being made. An electrocardiogram taken at that time disclosed an almost isoelectric T wave in Lead I. The disturbance of speech, weakness, and wasting of muscles were progressive over the succeeding three years. In July of 1949 the patient first noticed "fluttering" of the heart, which, at first, was intermittent but became constant for about one week prior to admission to the hospital. The past health record was of no importance.

The family history disclosed that the father had died at the age of 41 years as a result of an accident. He was supposed to have had "heart trouble." The patient's mother, as well as one brother, are living and well. The patient had two sisters, one of whom died at the age of 22 years of tuberculosis and the other at the age of 49 years of cancer. His son died at the age of 28 years of "heart trouble." The latter had progressive wasting of muscles, until his appearance was almost identical with that of the patient. He was found unfit for military service because of being underweight and having "heart trouble."

Physical examination disclosed a white man of small stature and slight build. The height was 52 inches, weight 97 pounds. He was well oriented. The voice was nasal, low pitched in quality, and at times difficult to understand. The gait was "slapping" in character. The eyes were sunken; the pupils were round and equal and reacted to light and accommodation. Slit lamp examination of the eye revealed many small opacities of approximately uniform size distributed evenly through the anterior and posterior portions of the cortex of the lens. Vision was 20/40 on the right and 20/30 on the left. The trachea was in the midline, and the lungs were clear to auscultation and percussion. The heart appeared to be slightly enlarged to the left. The apical impulse was exaggerated. No thrills or shocks were palpable. The rhythm was regular with a rate of 160 beats per minute. The sounds at the apex and the base were distant. No murmurs were audible. The abdomen, rectum, prostate, and genitalia revealed no abnormalities.

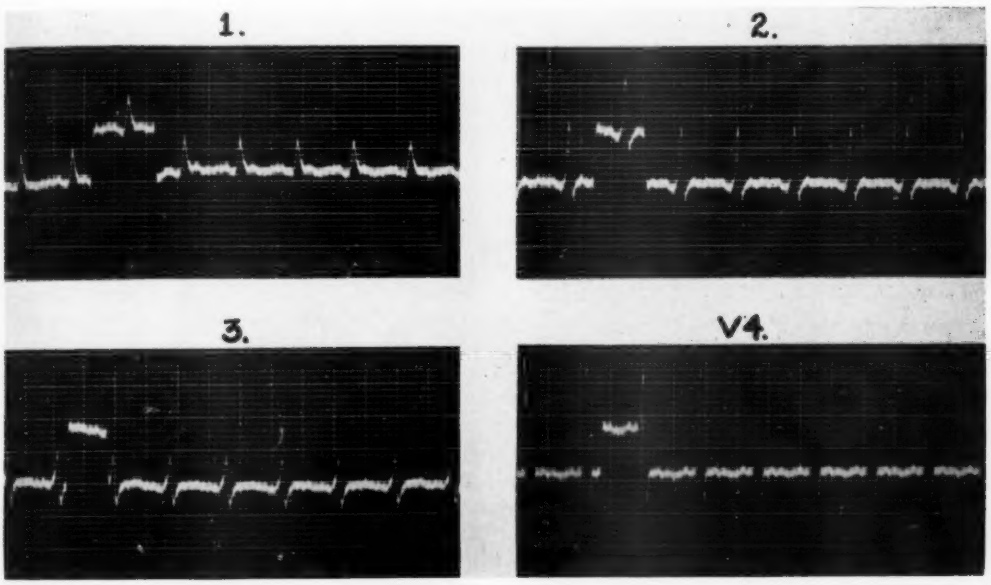

Fig. 2 (Case 1).—The electrocardiogram shows an auricular flutter with a 2:1 block.

Neuromuscular System.—The facies were typically myopathic with wasting of temporal muscles, weakness of masseters, orbicularis oculi and oris. The body of sternocleidomastoids was reduced to a few fibrous strands. There was generalized atrophy of scapular and supraclavicular muscles, as well as weakness and atrophy of the muscles of the upper and lower extremities. The latter was most marked in flexors of the wrist, small muscles of the hands, and the anterior and posterior tibial group. There was minimal myotonia of hand muscles. Superficial reflexes were normal. All deep reflexes were elicited, but these were markedly diminished.

The Kahn serological test was negative. Hemogram and urinalysis were normal. Basal metabolism rate was minus 37 per cent. Oral glucose tolerance curve disclosed a fasting sugar of 60 mg. per cent, one-half-hour sugar of 95 mg. per cent, one-hour sugar of 120 mg. per cent, and two-hour sugar of 115 mg. per cent. Total plasma proteins were 6.25 mg. with the albumin to globulin ratio 4:1. Roentgenological studies of the skull were normal. A chest examination September 7 was reported as follows: "There is moderate cardiac enlargement both to the right and to the left with apparently slight increase in the bronchovascular markings bilaterally" (Fig. 1). An electrocardiogram taken at the time of admission revealed an auricular flutter with a 2:1 block (Fig. 2).

On Sept. 10, 1949, the patient was given 1.4 mg. of digitoxin over a period of twelve hours. An electrocardiogram on Sept. 12, 1949, revealed fibrillation-flutter. Repeat electrocardiograms

on Sept. 19, 1949, and Sept. 29, 1949, disclosed sinus rhythm. The P-R and QRS intervals were normal. T waves in standard limb lead I and V_5 and V_6 measured less than 1 mm. in amplitude. There was no change in position of the S-T segment. A repeat roentgenogram done on Sept. 15, 1949 was reported as showing "approximately 2.5 cm. diminution in the transverse diameter of the cardiac silhouette since Sept. 7, 1949, with disappearance of the exaggeration of hilar markings." The patient was observed for thirty-four days and at no time did the irregularity of rhythm recur; the patient did not exhibit any further symptoms referable to the cardiovascular system.

CASE 2.—S. D., a 56-year-old white man, Syrian by birth, was admitted to the Veterans Administration Hospital on Jan. 17, 1949, because of dyspnea, generalized weakness, difficulty in swallowing, and progressive change in speech. History disclosed that the patient was in good health until 1939, when he noticed difficulty in swallowing. He found that deglutition was facilitated by drinking fluids. About the same time the voice became nasal in quality, and while prior to that date he had sung quite well, he noticed that he was unable to sing and his associates had difficulty in understanding his speech. Shortly thereafter, he became aware of a peculiar inability to straighten the fingers after grasping objects. However, he did not pay much attention to this because he became quite concerned by a rapidly progressing weakness of the upper and lower extremities. About three years after the onset of the first symptoms, he noted that the face was becoming thin, eyes somewhat sunken, and that he had some difficulty in keeping his mouth closed. He also developed marked weakness of the back and had to stoop forward while climbing stairs in order to retain his equilibrium. The weakness became progressively worse and was accompanied by atrophy of muscles. He denied loss of libido or any difficulty with his vision. About four months prior to admission to the hospital, while on a visit in Damascus, Syria, he developed exertional dyspnea. There was no associated chest pain, orthopnea, or pedal edema. He was seen by a physician in Damascus at which time a chest film revealed a greatly enlarged heart and an electrocardiogram showed left bundle branch block.

The family history was entirely negative. The patient's father had died of urinary retention at the age of 75 years. The mother was living and in good health at the age of 87 years. Three siblings were alive and in good health.

Physical examination disclosed a white man of medium height and slight build who appeared to be of about stated age. The height was 66 inches, weight 100 pounds. The patient was co-operative and of normal intelligence. His voice was nasal, low pitched, monotonous, and difficult to understand. He walked with a definite "slapping gait." The eyes were sunken deeply. The pupils were round and equal and reacted to light and accommodation. Slit lamp examination of the eyes disclosed that within the cortex of the lens "half way to the nucleus there were fine, small, irregular-shaped opacities. The nucleus was moderately sclerosed. These opacities, both in the anterior cortex and posterior cortex, were confined to a zone equidistant from the nucleus. The eyegrounds were normal." The thyroid gland was not palpable. The lungs were normal on percussion and auscultation.

The cardiovascular system showed the following: The heart was enlarged to the left with the point of maximal impulse in the sixth interspace 2 cm. outside the mid-clavicular line. The apical thrust was normal and no thrills or shocks were palpable. Auscultation disclosed a rate of 72 with occasional premature systoles. The heart sounds at the mitral area were slightly muffed and there was a Grade 1, blowing systolic murmur transmitted toward the sternum. The second pulmonic sound was accentuated. Blood pressure was 104 mm. Hg systolic and 72 mm. Hg diastolic. The peripheral vessels were easily compressible, and there was no evidence of arteriosclerosis. Abdomen, rectum, and testicles appeared to be normal. There was moderate kyphosis of the dorsal spine and a moderate lordosis of the lumbar spine.

Neuromuscular System.—Facies were characteristically myopathic. There was complete loss of temporal muscles and marked weakness of the masseters. The muscles of the eye and mouth were weak and atrophied; only a few strands of sternocleidomastoids were left. In addition, there was atrophy of the scapular, supraclavicular, and deltoid muscles, as well as of the muscles of the back. The musculature of the upper and lower extremities exhibited generalized atrophy, the relative extent of which was not recorded. After grasping an object the patient was able to extend the fingers very slowly, the small finger being the first to be extended completely,

followed by the ring, middle, and finally the index finger. Following each subsequent flexion of fingers, the extension became more rapid until it became normal. The phenomenon of myotonia could not be reproduced on testing other muscle groups. There was a partial bilateral foot drop. No deep reflexes could be obtained. The sensorium was intact.

The Kahn test was positive (2-3-3), Wassermann 4 plus, Kline 3 plus, and Mazzini 1 plus. Cardiolipin was negative. Hemogram and urinalysis were negative. Twenty-four-hour excretion of 17-ketosteroids was 15.8 mg. Roentgenologic examination of the skull was negative. Examination of the chest was reported as showing "marked cardiac enlargement with slight increase in vascular markings" (Fig. 3). An electrocardiogram revealed left bundle branch block (Fig. 4).

While under observation, the patient remained relatively asymptomatic, being able to attend to his own needs. At no time did he manifest signs of congestive failure. When last heard from, he was getting along well without apparent progression of cardiovascular symptoms.

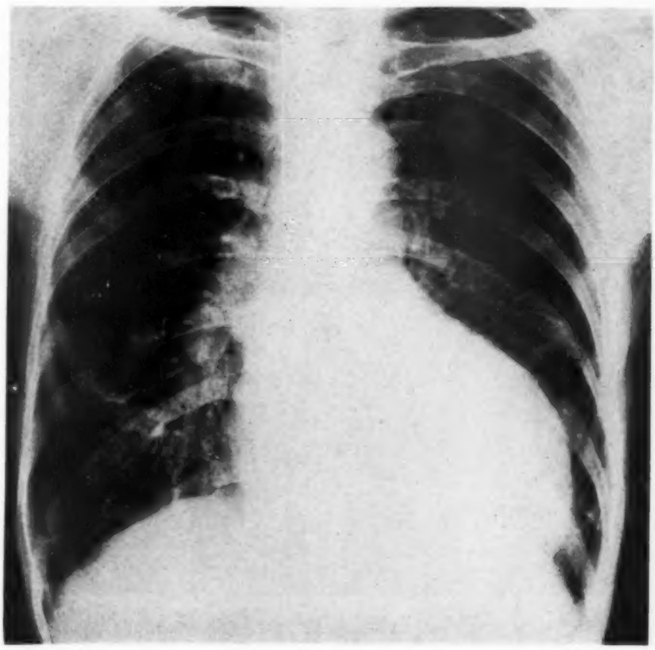

Fig. 3 (Case 2).—The roentgenogram of the chest shows marked cardiac enlargement with preponderance of the left ventricular component.

CASE 3.—K. F., a 42-year-old white man, a farmer by occupation, was admitted to the hospital on June 26, 1950. He was apparently well until about 1945, at which time he first noted inability to grasp and lift trays, associated with failure to relax his fingers in a normal manner. These symptoms became worse and were associated with definite weakness of the upper extremities and to a less extent of the lower extremities. He became fatigued and somewhat dyspneic on walking about one block. During the preceding three years, he had begun to have visual difficulty, having to focus for a prolonged period of time before being able to make out clearly any objects. Things had a tendency to run together. He denied any other difficulty.

Family history disclosed that the patient's mother had died of typhoid fever at the age of 25 years. His father is well and alive at the age of 67 years. One of his brothers died at the age of 38 years as a result of an accident. He had bilateral cataracts and was to be operated on at the time of death. His second brother also had bilateral cataracts which were treated surgically with apparently fair results; however, at the age of 38 years he developed "heart trouble" and died suddenly three years later.

Physical examination disclosed a white man, height 68 inches, weight 167 pounds. The patient was well oriented. His voice was nasal, low pitched, monotonous, and extremely difficult to understand. The eyes were sunken; the pupils were round and equal and reacted to light and accommodation. Slit lamp examination revealed a normal capsule. There was a concentric circle of polychromatic punctate opacities in the cortex completely surrounding the nucleus. The hard palate was narrow and extremely high. The trachea was in the midline; the lungs were clear to auscultation and percussion.

The cardiovascular system showed the following: The heart appeared to be normal in size. The apical impulse was not felt. No thrills or shocks were palpable. The heart sounds, both at the apex and base, were muffled and appeared to be distant. No murmurs were audible. The abdomen was negative. The testicles were markedly atrophied. The rectum and prostate revealed no abnormalities.

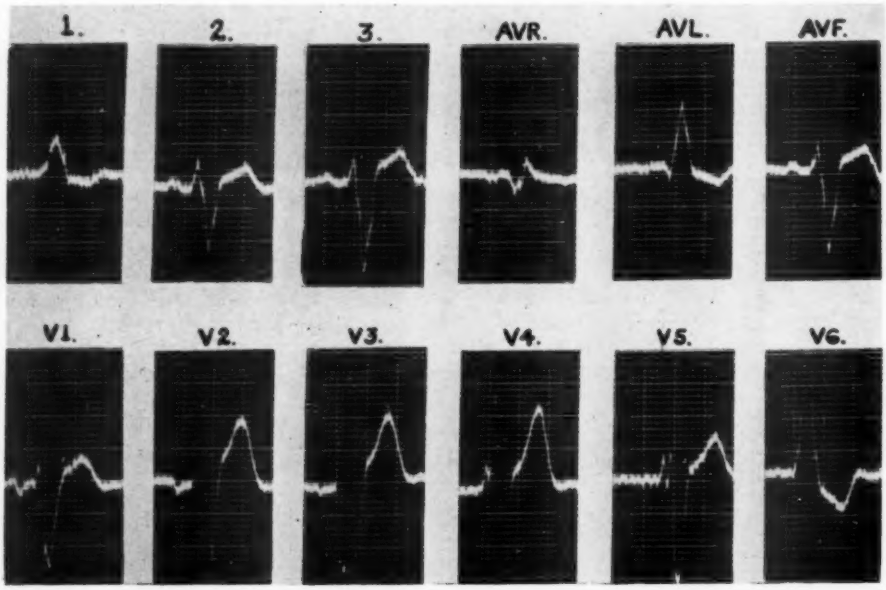

Fig. 4 (Case 2).—The electrocardiogram shows left bundle branch block.

Neuromuscular System.—The facies were typically myopathic. The forehead was smooth, and the patient was unable to wrinkle it. There was wasting of temporals, masseters, and orbicularis oris and oculi. The body of the sternocleidomastoids was reduced to mere strands, and the patient was unable to raise his head from supine position. There was generalized, moderate atrophy of the scapular muscles and the muscles of the upper and lower extremities. The weakness of the upper extremities was extreme, while that of the lower extremities was only moderate in degree. There was pronounced myotonia of the muscles of the hands. No deep reflexes were demonstrated.

Laboratory studies disclosed a normal hemogram and urinalysis. Serological tests for syphilis were negative. Blood cholesterol was 244 mg. per cent. The serum calcium and phosphorus were 11.5 and 1.5 mg. per cent, respectively. The alkaline phosphatase was 3.1 King-Armstrong units.

The roentgenographic examination of the chest and gastrointestinal tract was normal. The electrocardiogram showed a full P-R interval without any other significant abnormalities (Fig. 5).

While under observation, the patient did not develop any symptoms referable to the cardiovascular system.

CASE 4.—E. L., a 52-year-old white man, entered the hospital on Jan. 29, 1947, with the complaints of weakness, anorexia, and weight loss. Available history revealed that the patient had been discharged from the Army in 1919 with a diagnosis of tuberculosis for which he was treated intermittently until 1928, at which time the disease was thought to be inactive. Apparently, he got along fairly well until two years prior to admission when he noted progressive generalized weakness and a weight loss of about 50 pounds. This was associated with occasional episodes of vomiting.

The family history was noncontributory. Physical examination revealed a chronically ill-appearing white man who was described as being emaciated. He weighed 90 pounds at the time of admission. His speech was nasal in quality and thick. The eyes were sunken, and there was bilateral pseudoptosis. Slit lamp examination of the eyes revealed a few fine cortical opacities. These were small and discreet and seen in the anterior and posterior portions of the cortex. The chest was clear to auscultation and percussion. Blood pressure was 90 mm. Hg systolic and 60 mm. Hg diastolic. Examination of the heart revealed no abnormalities. The abdomen, rectum, prostate, and genitalia were normal.

Neuromuscular System.—The face showed atrophy of muscles with resultant myopathic facies. The sternocleidomastoids were reduced to fibrous strands. There was generalized muscular atrophy. No fibrillations were noted. The reflexes were greatly diminished. Marked myotonia of both hands was present.

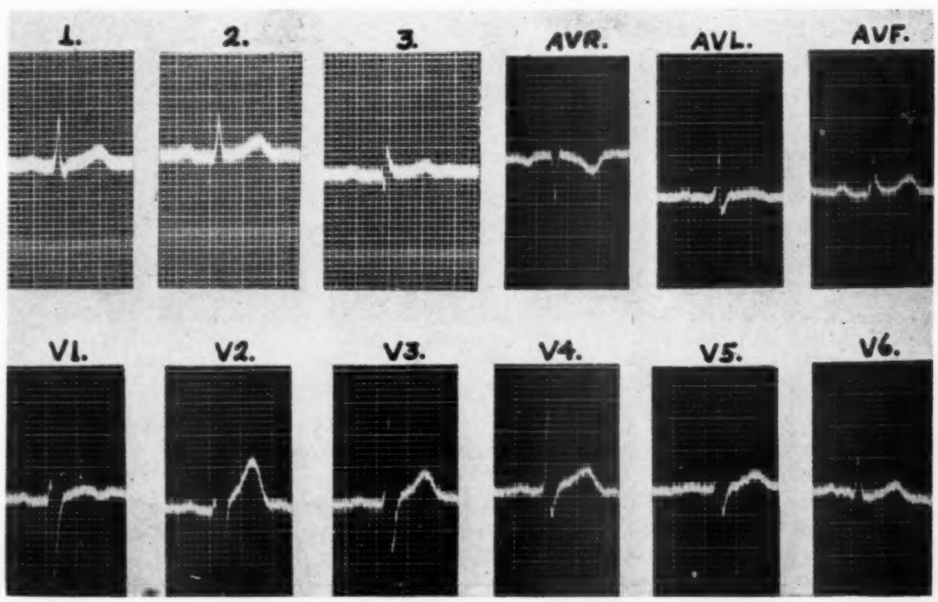

Fig. 5 (Case 3).—The electrocardiogram shows a P-R interval varying from 0.20 to 0.22 second.

Laboratory Studies.—The hemogram, urinalysis, and serological tests were normal. Basal metabolism tests were minus 15 and minus 8 per cent. Glucose tolerance curve, serum sodium, and potassium were normal. Roentgenographic studies of the chest revealed no abnormalities of the lung fields. The heart was normal as to size. The electrocardiogram disclosed a P-R interval measuring 0.20 second. The voltage of the QRS complexes in the standard limb leads was low. The T waves in standard Leads I and IV F were inverted (Fig. 6).

The hospital course was uneventful, and the patient was discharged after forty-five days of observation. Shortly after leaving the hospital, he was readmitted to another institution with the same complaints. While there, he suddenly died, the impression being that he died a cardiac death. Unfortunately no other information regarding the terminal episode could be obtained.

CASE 5.—J. H., a 35-year-old white man, was admitted to the hospital on Jan. 25, 1949, with vague complaints of weakness and weight loss. History disclosed that the patient was discharged from military service in 1944 after three years, because of "lack of adaptability." After being discharged from the service, he got along well until 1947 when he noticed progressive weakness and loss of weight. In addition, he became aware of inability to withstand cold weather because of numbness and tingling of the extremities on exposure to cold weather.

The family history did not reveal any similar illnesses.

Physical examination disclosed a white man of small stature. The height was 67 inches, weight 101 pounds. The patient's gait was typically "slapping" in character. The eyes were set deep in the orbits. The voice was low pitched and monotonous, and it was extremely difficult to understand his speech. The examination of the chest revealed no abnormalities. Blood pressure was 110 mm. Hg systolic and 60 mm. Hg diastolic. The heart did not appear to be enlarged to percussion. The cardiac sounds were extremely feeble with occasional premature systoles. No murmurs were present. The abdomen, rectum, and genitalia appeared to be normal.

Neuromuscular System.—The facies were typically myopathic. There was marked atrophy of neck muscles, and the neck curved back in a swan fashion. The sternocleidomastoids were absent. There was moderate atrophy of the triceps, the muscles of the forearm, the muscles of the hands, and the anterior tibial group of muscles. Moderate myotonia of both hands was present. All deep reflexes were diminished, but the sensorium remained intact.

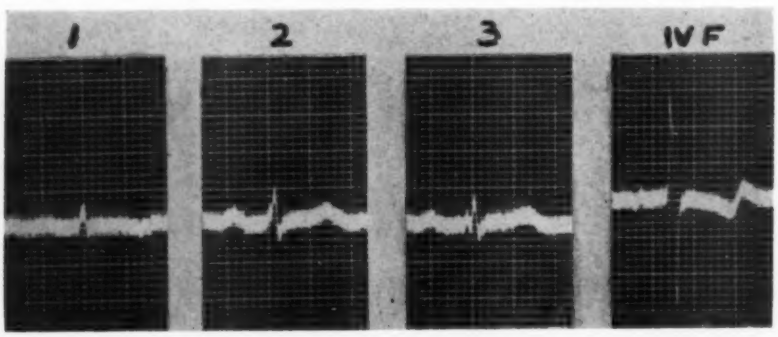

Fig. 6 (Case 4).—The electrocardiogram shows a P-R interval of 0.20 second, low voltage QRS complexes in the standard leads, inverted T wave in Lead I, and diphasic T wave in IV F.

Laboratory Studies.—The hemogram, urinalysis, and serological tests were normal. The oral glucose tolerance curve was 80 mg. per cent, 143 mg. per cent, 121 mg. per cent, 79 mg. per cent, and 60 mg. per cent, fasting, one-half hour, one hour, two hours, and three hours, respectively. The serum calcium and phosphorus were 10.9 mg. per cent and 4.0 mg. per cent, respectively. Basal metabolism tests were minus 11 and minus 4 per cent on two occasions. The roentgenologic studies of the chest, skull, and lumbar spine revealed no abnormalities. The electroencephalogram disclosed a normal pattern. The electrocardiogram showed a sinus rhythm with a rate of 72. There was an occasional auricular premature systole. The P-R interval measured 0.20 second and the QRS interval 0.10 second (Fig. 7).

The hospital course was uneventful. The patient was ambulatory throughout and at no time exhibited symptoms directly referable to the cardiovascular system.

REVIEW OF THE LITERATURE

Electrocardiographic Changes—In 1920, Maas and Zondek[7] reported a case of a 45-year-old man who, in addition to dystrophia myotonica, exhibited changes of the cardiovascular system manifested by hypotension, bradycardia, distant heart sounds, generalized cardiac enlargement, and prolongation of the

P-R interval. In 1923, Adie and Greenfield[8] obtained a normal electrocardiogram from one of their patients. Guillain and Rougues[9] obtained electrocardiographic tracings in five of their patients, three of whom showed lengthening of the P-R and/or QRS intervals. Two years later, Curschmann[10] reported an instance in which the P-R interval varied from 0.27 to 0.29 second. Thaysen[11] described two families with nine unquestionable and eight probable cases of dystrophia myotonica in two generations. Four of his patients were studied electrocardiographically, and in all of these the P-R interval was prolonged. In 1944, Biork[12] studied a family consisting of the father, two sons, and a daughter, and he found that all four had abnormal electrocardiograms. The findings consisted of prolongation of the P-R interval in one and prolongation of the P-R and QRS intervals in another. The third and fourth members of the family exhibited prolongation of the P-R interval associated with a transient auricular flutter. Evans[13] studied thirteen patients with dystrophia myotonica and found that in none of them did the P-R interval measure less than 0.20 second. It was 0.24 second or greater in five, and in two it was 0.30 and 0.31 second, respectively. In a series of 14 cases observed by Segura and Lanari[18] and Ask-Upmark,[23] there were nine individuals with normal electrocardiograms.

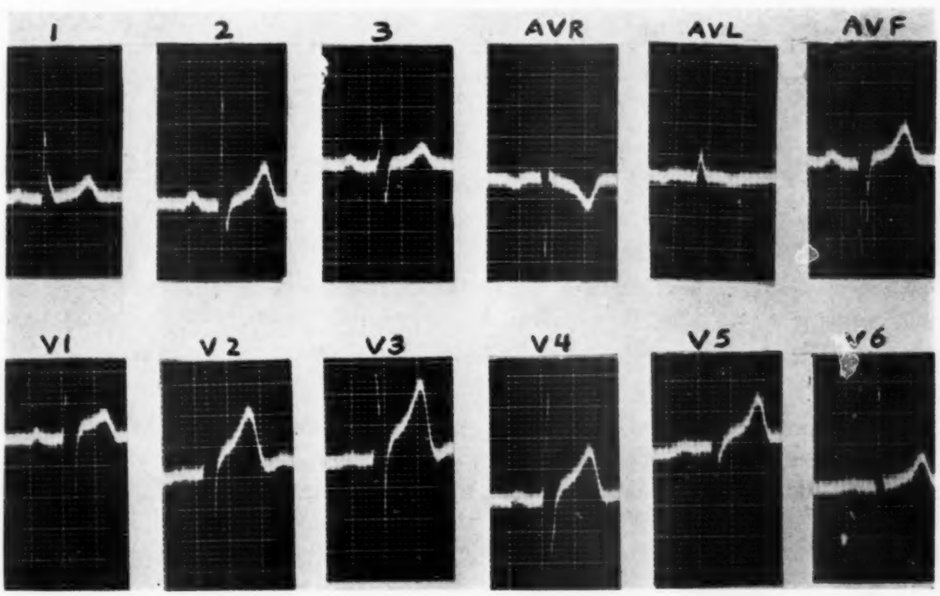

Fig. 7 (Case 5).—The electrocardiogram shows a P-R interval of 0.20 second and a QRS interval of 0.10 second

Including the six cases presented in this paper, the author was able to collect a total of 85 instances in which electrocardiographic studies were done.[7-29] The electrocardiographic changes are summarized in Table I and their distribution according to age, when known, is given in Table II.

TABLE I. SUMMARY OF ELECTROCARDIOGRAPHIC CHANGES

	CASES		PER CENT
Normal	27		31.7
Altered P-R interval	41		48.3
P-R of 0.20 second		7	
With inverted T wave		1	
P-R over 0.20 second		17	
With prolonged QRS and intermittent 2° block		2	
With prolonged QRS		10	
With prolonged QRS and transient flutter		1	
With transient flutter		1	
With low T wave		2	
Prolonged QRS	10		11.7
Transient auricular flutter	1		1.2
Transient auricular fibrillation	1		1.2
Left ventricular preponderance	1		1.2
Nonspecific S-T changes	1		1.2
Low T waves	3*		3.5
Total	85†		100.0

*In one instance the changes were thought to represent myocardial infarction.
†In fourteen instances the P waves were described as being low.

TABLE II. DISTRIBUTION OF ABNORMAL ELECTROCARDIOGRAMS ACCORDING TO AGE

AGE (YEARS)	-20	21-25	26-30	31-35	36-40	41-45	46-50	50-
No. of electrocardiograms	5	5	9	15	12	20	6	8
Per cent of abnormality	20	60	77.7	80	50	75	66.6	75

Symptoms Referable to the Heart.—In only six of the 83 were the symptoms referable to the heart of such a degree as to become presenting symptoms. Evans[13] reported that two of his patients complained of dyspnea on exertion. Both of these patients had cardiac enlargement. Palpitation was a presenting symptom in one of the cases described by Mondon and Pasquet[15] and in another reported upon by Fagin.[26] In two of the five patients seen by this author the presenting symptoms were palpitation and exertional dyspnea, respectively.

Pulse.—The pulse rate was found to be below 60 beats per minute in four patients and below 50 in another nine patients.

Blood Pressure.—Thirteen individuals exhibited a systolic blood pressure below 100 mm. Hg and another 14 below 110 mm. Hg systolic. There were only three individuals who had a systolic blood pressure above 140 mm. Hg; in none of them was it higher than 160 mm. Hg.

Auscultatory Findings.—Splitting of the first sound at the apex was described in 11 cases,[13,18] the sounds were distant in seven[8,13] and soft systolic

apical murmurs were encountered in 10 instances.[12,13,17,18,29] In all instances the murmurs were thought to be functional in origin.

Heart Size.—Slight enlargement of the heart was noted in three cases,[9,13] moderate enlargement in five,[13,15,23,25] and marked enlargement in two.[7] The last group includes Case 2 of the present series. There was no relationship found between the length of the P-R interval and heart size, as proposed by Evans.[13]

Autopsy Findings.—There have been a few cases of dystrophia myotonica studied anatomically, but the examinations of the heart were in the majority of instances most inadequate. The reason for this is well understood, for most examiners focused their attention on the alterations of the nervous and muscular systems. In the cases in which the heart was examined, with a few exceptions there was a complete lack of clinical history which would allow one to make a reasonable correlation between the cardiac status prior to death and the autopsy findings. Adie and Greenfield[8] were the first ones to perform an autopsy on an individual suffering from dystrophia myotonica. Their patient was a 39-year-old man whose heart was healthy when studied anatomically. Segura and Lanari[18] found the heart to be normal in an individual who, prior to his death, exhibited faint heart sounds, a blood pressure varying from 94/64 to 104/92 mm. Hg, and electrocardiographic changes consisting of elevated S-T segments in standard Leads I and II. Keschner and Davison[11] found marked increase in epicardial fat and fatty infiltration of the wall of both ventricles and of the papillary muscles. They observed actual fatty replacement of the heart musculature although "the myocardium was better preserved than the striated muscle." Aranovich[30] gave a gross description of a patient he studied who died at the age of 43 years of "cardiac syncope." There was passive congestion of the lungs, liver, and spleen. Histological examination was lacking. Fagin[26] found a hypolastic heart weighing 275 grams. According to the author, the cardiac muscle exhibited atrophy.

Black and Ravin[31] reported pathological findings in five patients. The first case was a 44-year-old white man who, during life, had no symptoms referable to the cardiovascular system. The blood pressure varied from 96 mm. Hg systolic and 64 mm. Hg diastolic in the recumbent position to 104 mm. Hg systolic and 72 mm. Hg diastolic in the sitting position. The heart sounds were faint, but no other abnormalities were noted. The electrocardiogram showed a somewhat high take-off of the S-T segment in Lead I (1 mm.) and in Lead II (1 mm.). The patient died from intercurrent pulmonary infection. At autopsy the heart weighed 420 grams and was grossly normal. Microscopic examination was recorded as follows: "Sections of right and left ventricular myocardium showed moderate variability in size of fibers with variation in nuclear size and shape. Cross striations were well defined in all fibers. The number of nuclei was not increased over the normal, and clumping of nuclei as seen in skeletal muscle was lacking."

Their second case was a 43-year-old white man who died as a result of skull fracture. The blood pressure prior to death was recorded as 100 mm. Hg systolic and 68 mm. Hg diastolic, and the pulse rate was 56 per minute. The heart sounds were faint, but no other abnormalities were noted. At necropsy the heart

weighed 340 grams and appeared normal grossly. No histological examination was described.

The third case was that of a 67-year-old woman who died as a result of aspiration pneumonia. Her blood pressure was 104 mm. Hg systolic and 70 mm. Hg diastolic. The first apical sound was of moderate intensity with a "fairly loud high-pitched" systolic murmur at the apex. A roentgenogram of the heart and electrocardiogram were normal. At autopsy the heart was "essentially normal."

The fourth and fifth patients had hearts weighing 310 and 250 grams, respectively, and both were normal on gross examination. In the former the histological examination did not disclose the changes usually seen in the skeletal muscle.

COMMENT

The six patients studied by the author all presented the characteristic clinical features of dystrophia myotonica. In four of the five patients with abnormal electrocardiograms it was not possible to obtain a history which would suggest that the alteration might be a result of one of the more common etiological causes. In Case 2, the serological test for syphilis was positive, and syphilis could conceivably be implicated as causing the cardiac lesion. However, careful examination on a number of occasions failed to disclose any findings usually associated with syphilitic heart disease. The cases reported in the literature were conspicuous for the absence of an antecedent history of rheumatic fever, syphilis, hypertension, or symptoms of angina pectoris or myocardial infarction.

In 68.3 per cent of the collected series the electrocardiogram deviated from normal, and in 91.3 per cent of this group the alteration consisted of a conduction defect and/or disturbance of rhythm. In only occasional patients was there any abnormality of the T waves, and only in one instance[17] were the changes considered to be due to myocardial infarction. There was a uniform distribution of the abnormal electrocardiograms among the various age groups (Table II).

The etiology of dystrophia myotonica and, consequently, the manner in which the heart is affected remains obscure. It is safe to assume as did Maas and Zondek[7] and Segura and Lanari[18] that the heart does not participate in myotonic contractions. The latter two came to this conslusion after detailed clinical electrocardiographic and radiographic investigations, including the measurement of the electrical and mechanical systole. Maas and Zondek[7] were the first to propose, with caution, that the entire picture of this disease including the cardiac component may be related to some endocrine dysfunction, but they added that further studies are needed to elucidate this point. Biork[12] subscribed to the endocrine theory, but added that its effect may be mediated through the autonomic nervous system. Maas and Patterson,[6] having found changes in the heart blood vessels, skin, respiratory, alimentary, endocrine, and reproductive systems, expressed the opinion that the multitude of changes point to the involvement of the autonomic nervous system; however, the exact relationship remains obscure. That the various disorders of cardiac rhythm may be due to dysfunction of the autonomic nervous system and, more specifically, to

hyperactivity of the vagus is supported by a number of the writers.[18,22,23] Waring and associates[17] believed that the type of electrocardiographic finding in their series suggests that coronary sclerosis, rather than a dystrophic process of myocardium, is responsible for the observed changes. This view has not been subscribed to by any of the other authors.

The available anatomical studies are so meager that no opinion as to the pathological changes of the myocardium in dystrophia myotonica can be expressed at this time. However, the high incidence of electrocardiographic abnormalities, the type of alteration, their uniform distribution among the various age groups, coupled with other, but less common cardiac abnormalities and a conspicuous lack of antecedent history of one of the more common etiological agents, suggest strongly that the alterations of the cardiovascular system are an integral part of dystrophia myotonica rather than a coincidental finding. Should further studies confirm this supposition the treatment directed toward the preservation of the cardiovascular system may become an important part of the over-all management of the individual suffering from this disorder.

SUMMARY

1. Five patients with dystrophia myotonica and abnormal electrocardiograms are presented.

2. The literature dealing with the heart in this disorder is reviewed. Abnormal tracings were found in 68.3 per cent of the eighty-five patients studied electrocardiographically. Other alterations of less frequency consisted of bradycardia, hypotension, cardiac enlargement, splitting of the first heart sound at the apex, muffling of the heart sounds, and apical systolic murmurs.

3. The lack of detailed anatomical studies of the heart is stressed.

4. The possibility that the heart is affected by the underlying, but yet unknown, disorder of dystrophia myotonica is offered.

I wish to express my gratitude to Dr. P. D. Genovese for his helpful suggestions, to Miss Lucy Cole who obtained much of the reference material, and to Miss Virginia Allen for her secretarial aid.

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THE INTENSITY OF THE FIRST HEART SOUND IN AURICULAR FIBRILLATION WITH MITRAL STENOSIS

ABE RAVIN, M.D.,* AND EDWARD BERSHOF, M.D.**

DENVER, COLO.

IN A recent publication[1] it was stated that in patients with auricular fibrillation and mitral stenosis there was "little variation in the peak amplitude of the first heart sound at different times in diastole." It is the purpose of this article to show that in many instances of mitral stenosis with auricular fibrillation there is a marked variation in the intensity of the first heart sound at different times in diastole, and that this variation often bears a definite relationship to the length of the preceding diastole.

METHOD

Simultaneous heart sound and electrocardiographic records were taken on two patients with auricular fibrillation without mitral stenosis and on ten patients with auricular fibrillation and mitral stenosis. Part of the records were taken on a Cambridge stethocardiograph and the remainder on a Sanborn Tri-Beam. The records were taken from the apical area and, in cases of mitral stenosis, usually in the area in which the diastolic murmur was loudest. The patients were recumbent. The records were all taken during quiet respiration.

Although it is true that the intensity of the sound as heard by the ear depends on more than the amplitude of the greatest vibrations as recorded, this method of roughly comparing intensity has been accepted by many workers in the field[2,3,4] and is justified on the basis of personal experience. The term "intensity of first sound" as used in this article refers to the measurement thus obtained, and, although the shortcomings of the method are recognized, it is felt that no real error is introduced. For purposes of graphing, the amplitude as obtained in millimeters was at times changed to arbitrary units. The sum of the three largest vibrations seemed to us to be a more accurate index of what was seen than measurement of a single vibration, but it is doubtful if the general trend of the data would show an appreciable difference in the two methods. It is obvious that comparisons can only be made between complexes in a single record.

The intensity of the first sound, as obtained by the foregoing method, was graphed against the time interval from the beginning of the preceding second

From the Cardio-Pulmonary Laboratory of the National Jewish Hospital and the Department of Medicine of the University of Colorado School of Medicine, Denver.

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*Director, Cardio-Pulmonary Laboratory of the National Jewish Hospital; Associate Clinical Professor of Medicine, University of Colorado School of Medicine.

**Clinical Instructor in Medicine, University of Colorado School of Medicine.

sound to the beginning of the first heart sound in question. Since this time interval is usually considered the duration of ventricular diastole,[5] it has been so labelled in the graphs.

There are certainly other factors which can and do affect the intensity of the first heart sound besides the duration of ventricular diastole. When patients either breathe or hold their breath during registration of heart sounds, factors are brought into play which could affect these sounds. The duration

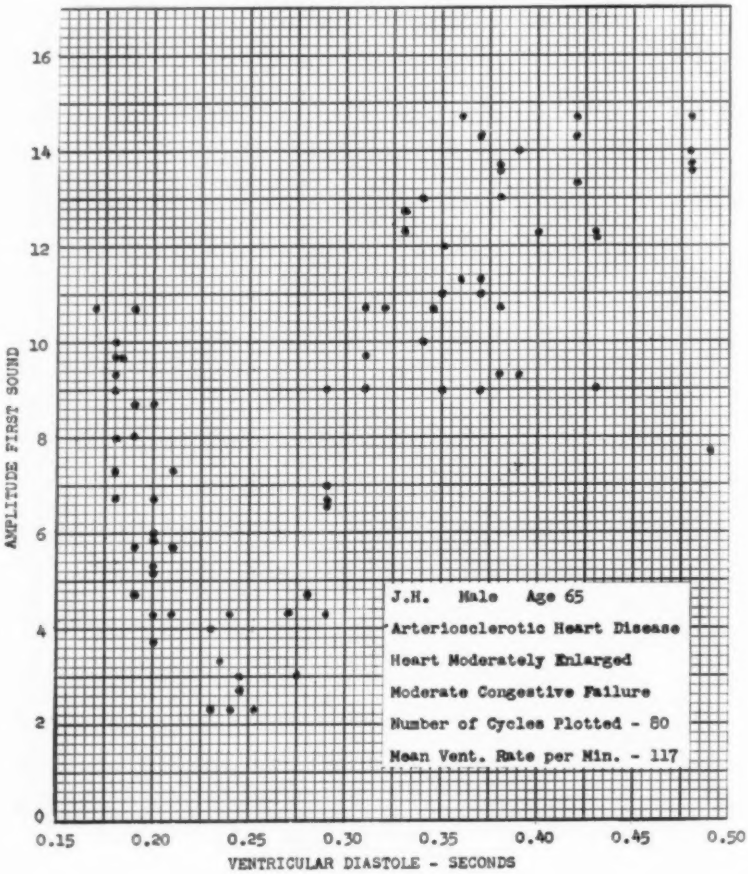

Fig. 1.

of diastole in the beat or two preceding the one under consideration seems to be of importance. These and other factors would, however, disrupt the relationship between the first sound intensity and the duration of the preceding ventricular diastole, and therefore any clear relationship between the two would be so much more important.

RESULTS

Figs. 1 and 2 illustrate the relationship of the first sound intensity to the duration of preceding ventricular diastole in two patients with auricular fibrillation without mitral stenosis. These were the only two patients without mitral

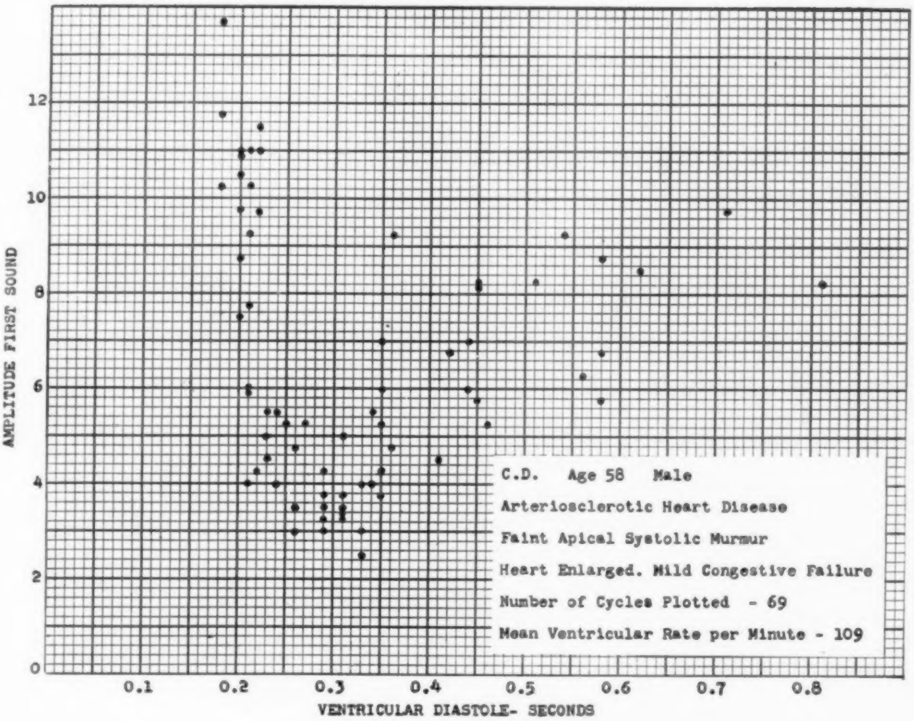
C.D. Age 58 Male
Arteriosclerotic Heart Disease
Faint Apical Systolic Murmur
Heart Enlarged. Mild Congestive Failure
Number of Cycles Plotted - 69
Mean Ventricular Rate per Minute - 109
AMPLITUDE FIRST SOUND
VENTRICULAR DIASTOLE- SECONDS

Fig. 2.

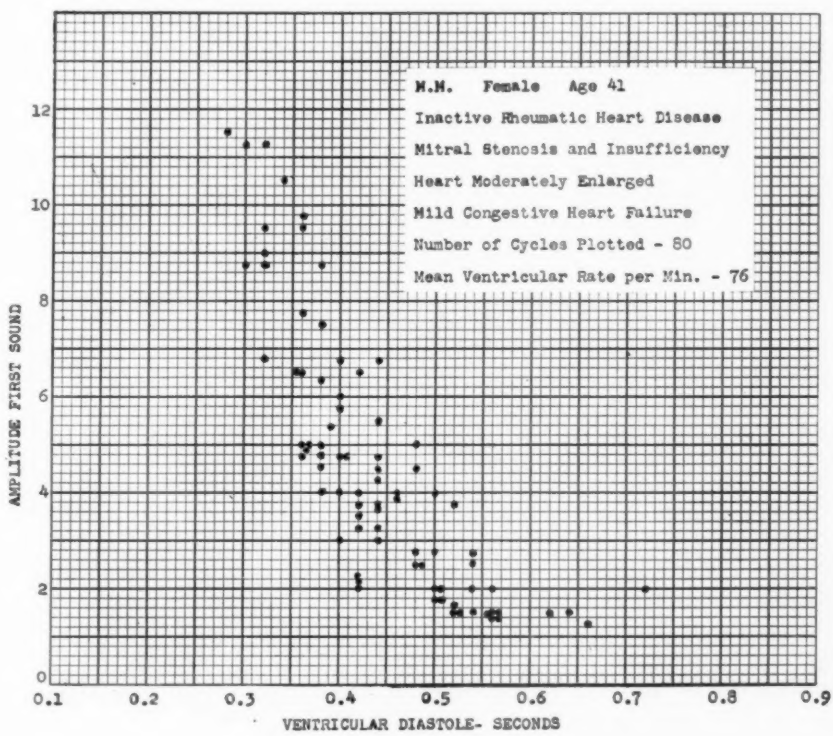
M.M. Female Age 41
Inactive Rheumatic Heart Disease
Mitral Stenosis and Insufficiency
Heart Moderately Enlarged
Mild Congestive Heart Failure
Number of Cycles Plotted - 80
Mean Ventricular Rate per Min. - 76
AMPLITUDE FIRST SOUND
VENTRICULAR DIASTOLE- SECONDS

Fig. 3.

stenosis in whom records were taken, and they are therefore not selected. They are similar to the figures published by Rytand[1] and are presented here for comparison with the patients with auricular fibrillation with mitral stenosis. The striking feature of these two curves was the occurrence, some 0.21 to 0.22 second after the second sound, of a short period during which the first sound

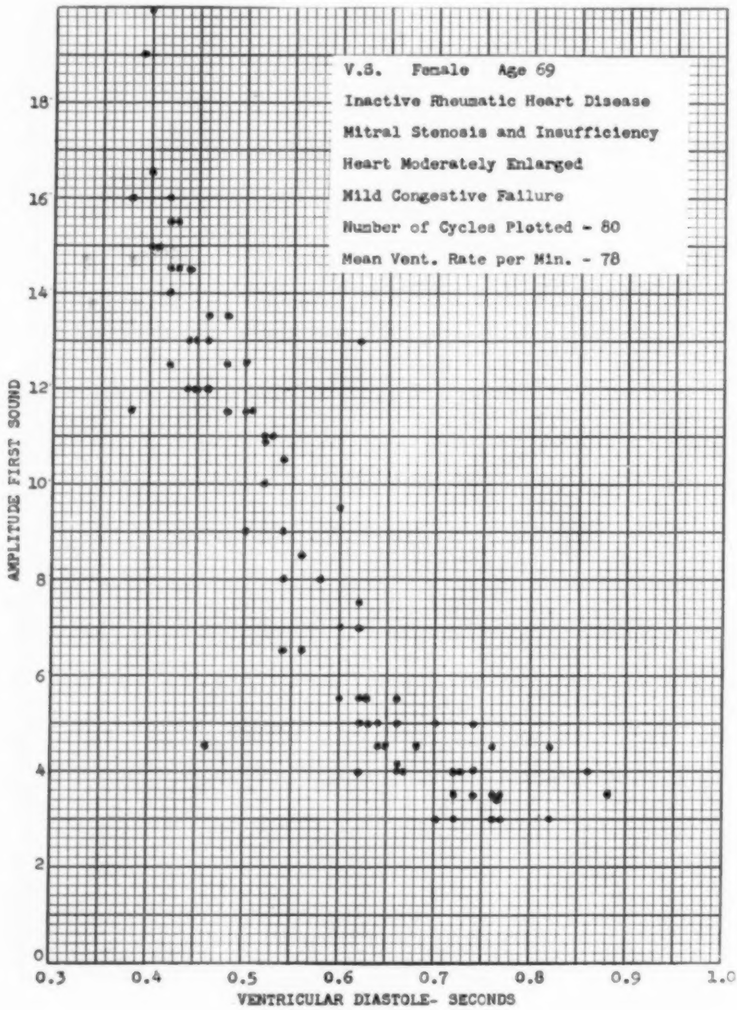

Fig. 4.

was markedly diminished. The intensity of the first sound was loud very early in diastole, fell sharply to a low level at about 0.21 second after the second sound, remained low for 0.08 (Fig. 1) to 0.12 (Fig. 2) second, and then rose sharply and remained at a high level.

Of the ten records taken on patients with auricular fibrillation and mitral stenosis, only five are presented here. Figs. 3, 4, 5, and 6 are shown because

they demonstrated such a clear-cut relationship between the intensity of the first sound and the duration of ventricular diastole. Fig. 7 is shown as an example of the remainder in which no such relationship was usually evident. Since some of the records were taken because the presence of the desired relationship was recognized clinically, the percentage of patients showing the correlation in this group is greater than the percentage in all patients with mitral stenosis.

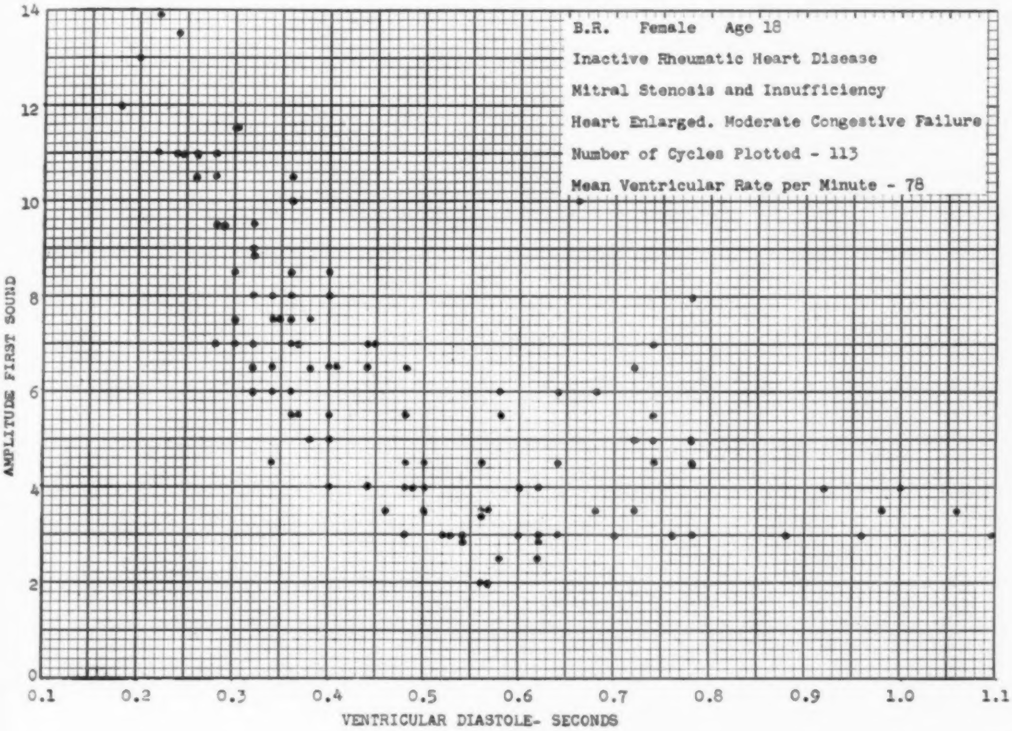

Fig. 5.

Examination of Figs. 3, 4, 5, and 6 shows what was evident on clinical auscultation of these patients. The first sound was loudest when the contraction occurred in early diastole, and there was a gradual fall in the intensity of the first sound as the duration of diastole increased, until a low intensity was reached and maintained. Since other factors besides duration of diastole must be in action, this correlation is indeed striking.

DISCUSSION

Figs. 1 and 2 confirm, in general, the statement made by Rytand[1] that in patients with auricular fibrillation without mitral stenosis the peak amplitude of the first sound "is greatest when its onset falls soon after the preceding sound, at a time coinciding with that of the gallop (if present); it then diminishes quickly

through the next tenth of a second to values 23 to 44 per cent (mean 37) of its early height; later in diastole it may continue at its low level or increase again toward or even beyond the high early magnitude." It was the short period of decreased intensity of the first heart sound which was the most characteristic feature in this group of patients. The relative intensities of the first heart sound before and after this period of low intensity may show marked variation.

Experimental work in recent years indicates that the intensity of the first heart sound is mainly dependent on the position of the mitral and tricuspid valves at the moment of ventricular systole. Although there is some difference of opinion as to how the position of the valves influences the intensity of the sound,

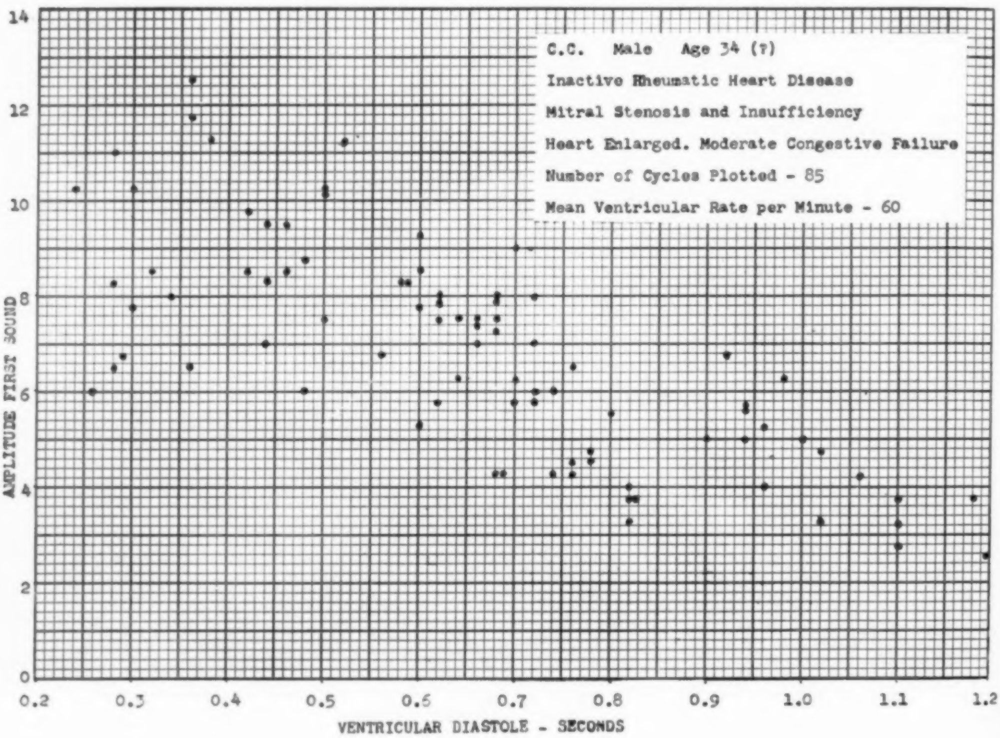

Fig. 6.

the authors feel that the explanation given by Dock[3] seems to explain most phenomena in the clearest manner. According to Dock, if the valves are widely open at the moment of ventricular systole, the valves are drawn taut sharply and produce a loud first heart sound. If the valves have floated toward each other and are partially taut at the moment of ventricular systole, the sound produced by their closure is much less. The short period of diminished first sound in auricular fibrillation without mitral stenosis as seen in Figs. 1 and 2 can thus be interpreted as indicating that at this time the valves have floated toward each other and are partially taut. Immediately preceding this is the period of

rapid diastolic filling when the valves would be expected to be wide apart and the first sound loud. It would appear that immediately following the first rapid inflow of blood in early diastole, and as the stream slows down, the valves are thrown up toward the position of closure just as they are when the stream slows down at the end of auricular systole.[6] In most instances, they then float apart and may be as widely open as they are during the phase of rapid diastolic filling.

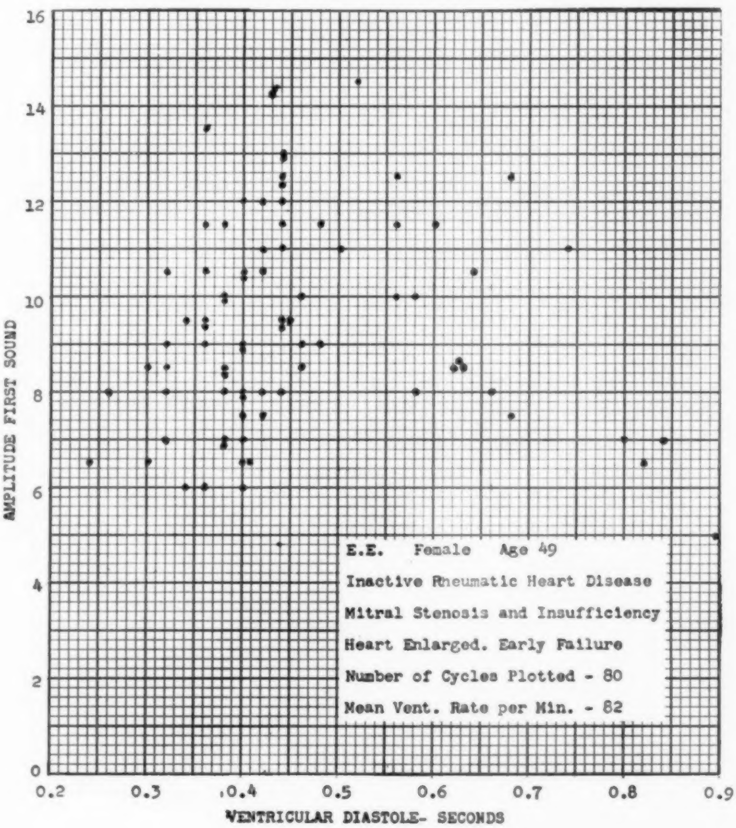

Fig. 7.

Assuming that valvular position determines intensity of the first heart sound, one might on a priori reasoning picture three possibilities in auricular fibrillation with mitral stenosis. (1) With very early and mild degrees of stenosis the action of the valves might show very little difference from that found in auricular fibrillation without mitral stenosis, and the same curves seen in those instances would occur. Since early mitral stenosis does not usually produce fibrillation, few patients would be found in this category. (2) At the other extreme, when the valve is very rigid and can move little, if at all, one would expect very little variation in the first heart sound, and what variation would occur would depend on factors other than valvular position. A fibrotic, and therefore more rigid, valve, even though free to move, would not be capable of the same variations

in tenseness as a normally flexible valve. Although the fibrotic valve might therefore produce a loud sound when put under sudden tension, it would not seem to be capable of producing the variations in sound which might be expected of a normal valve. (3) Finally, there would be a group of intermediate patients, some of whom would have a moderate degree of stenosis and valves that were still flexible and capable of some motion. In these patients, because of the stenosis, there is a prolonged phase of rapid diastolic filling. As the ventricle fills and ventricular pressure slowly rises, there is a gradual slowing of the stream and a gradual falling together of the valve leaflets. At no time does the stream slow suddenly enough to throw the mitral leaflets together. In these patients the sounds would be loud early in diastole and gradually fade in intensity. This would explain the type of curve seen in Figs. 3, 4, 5, and 6.* In all of these patients the stenosis was very definitely the predominant lesion as judged by the intensity of the systole and diastolic murmurs.

The observation that the intensity of the first heart sound decreases with increasing duration of diastole strikingly points out the relative unimportance of the strength of ventricular contraction on intensity of the first heart sound. After long diastoles the ventricles are full, have a greater initial pressure, and contract forcibly; nevertheless, the intensity of the first heart sound is less than after short diastoles when the ventricles do not contract as forcibly. This observation does not rule out the possibility that, given the same valvular position, a more forcible ventricular contraction would produce a louder sound than would a weaker contraction. This is true in the case of the semilunar valves where a higher closing pressure produces a louder sound.[2] The vibrations of the first heart sound reach their maximum intensity during the isometric period of ventricular systole. The tension developed during the isometric phase, therefore, would seem of greater importance than the total ventricular tension in influencing the intensity of the first heart sound.[2] The tension developed during the isometric phase depends on the arterial diastolic pressure. In auricular fibrillation the diastolic pressure decreases as diastole lengthens.[7] The isometric tension developed, therefore, decreases as the duration of diastole increases. All other factors being equal, it is possible that the intensity of the first heart sound would decrease as diastole increased. It is conceivable that if the valve were completely rigid and immobile, the intensity of the first sound would decrease with increasing length of diastole due to decrease in tension developed during the isometric phase of contraction. Because of the relative unimportance of ventricular contraction in influencing the intensity of the first heart sound (Figs. 1 and 2), this explanation for a marked variation in intensity of the first sound (Figs. 3 and 4) seems very unlikely.

Since the sound records were taken from the area (usually at or near the apex) where the first sound and diastolic murmur were loudest, the first sound would be expected to be mainly of mitral origin. The tricuspid valve in these patients was considered to be normal. That portion of the first sound produced by the tricuspid valve, therefore, should show the variation seen in fibrillation

*In Rytand's figures, this relationship is nicely shown in Fig. 12 and to a lesser extent in Cases 6, 7, and 8.

without stenosis (Figs. 1 and 2). The faintness of the first sound in the apical area after long pauses would indicate that the tricuspid valve contributes very little to the first sound in that area. It is our impression, confirmed, however, by sound recordings on only one patient (V.S.), that in those instances in which the first sound at the apex shows a clear relationship to length of diastole, the first sound in the fourth and fifth interspaces next to the sternum shows this relationship to a much less degree, if at all.

In some patients with mitral stenosis, contractions occurring very early in diastole seem to produce first sounds of less intensity than contractions occurring slightly later.[1] It is possible that this is not a true observation and that what is seen is the variation which might be expected from the method used and from factors not considered, especially the influence of the duration of diastole in cycles immediately preceding the cycle being considered. If it does occur, however, it may possibly be related to the very small amount of blood which the ventricles must contain early in diastole in instances of marked mitral stenosis.

Only a casual glance at Figs. 1 and 2 is needed to convince one that it is folly to assume that the ear could pick out the one-tenth of a second of diminished first sounds among the remainder. This feature is of little or no value as a diagnostic sign. On the other hand, when the first sound in mitral stenosis is related to diastolic duration, the relationship is recognized without great difficulty. The diagnostic value of this sign is not great, however, since the diastolic murmur is usually very evident.

SUMMARY

Simultaneous phonocardiographic and electrocardiographic tracings were taken on ten patients with auricular fibrillation and mitral stenosis and two patients with auricular fibrillation without mitral stenosis. In each instance the intensity of the first heart sound, as gauged by totalling the amplitude of the three largest vibrations of the first sound, was plotted against the duration of the preceding ventricular diastole.

In six of the patients with mitral stenosis there was no definite relationship between the intensity of the first sound and the duration of the preceding ventricular diastole.

In four patients with mitral stenosis there was a clear-cut and striking relationship: The intensity of the first sound varied, within limits, inversely as the duration of ventricular diastole. The first sounds were loud when diastole was short and became less intense as diastole lengthened, until a low intensity was reached and maintained.

The type of variation of the first heart sound seen in these four patients differs from the variation that occurs in patients with auricular fibrillation without mitral stenosis.

Possible explanations for the variation in the first heart sound intensity are discussed.

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CONGENITAL TRICUSPID ATRESIA

IRVING G. KROOP, M.D.*

NEW YORK, N. Y.

TRICUSPID atresia is a rare but important congenital cardiac defect. Abbott[1] reported an incidence of 1.6 per cent in 1,000 collected autopsies of congenital heart disease. Edwards and Burchell[2] recently reviewed the literature and reported a total of forty-five cases which included three cases of their own. Three cases with autopsies have been published since then.[3,4,5] The clinical incidence may be somewhat greater. An incidence of five cases in 135 patients with congenital heart disease has been reported by Fell and associates.[4] Baker and co-workers[6] found three cases among fifty cyanotic patients who came to operation. Of 350 cyanotic patients studied by Taussig,[7,8] thirty-seven were atypical; fifteen of these showed left axis deviation and may have had tricuspid atresia. Potts and associates[9] encountered this defect six times in 117 patients with cyanotic congenital heart disease.

Despite its low incidence, tricuspid atresia is an important lesion to be considered in the preoperative diagnosis of a cyanotic congenital cardiac patient with left axis deviation. The anatomical type of tricuspid atresia must be determined accurately before an aortopulmonary shunt is contemplated. In cases of tricuspid atresia the Blalock-Taussig operation and the Potts operation have been performed with good results. It is also possible that a surgical procedure which enlarges the interatrial defect in tricuspid atresia may prolong the life of the patient.[10] The experience of Fell and associates,[4] indicating that the Potts procedure is technically feasible in the first months of infancy, is most encouraging because most patients with tricuspid atresia die in infancy.

The two cases presented in this report illustrate certain anatomical and clinical features which are important in the preoperative evaluation of tricuspid atresia.

CASE REPORTS

CASE 1.—F. R., a white infant 5 months old, was admitted because of cough, diarrhea, and failure to gain weight. The birth weight was 4 pounds 4 ounces at term and 5 pounds 7 ounces at 5 months. At the age of 4 weeks the patient was hospitalized elsewhere because of a nonproductive cough. The diagnosis made at that time was cyanotic congenital heart disease complicated by bronchopneumonia and atelectasis. The patient responded well to sulfadiazine and oxygen. However, the appetite was feeble, and the infant was admitted to a second hospital for further study. The diagnosis was congenital heart disease with retardation of growth and

From the Cardiographic Department and the Cardiovascular Research Group, The Mount Sinai Hospital, New York.

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*Dazian Fellow and Sara Welt Fellow in Medicine, The Mount Sinai Hospital. Present address: Department of Cardiology, Jewish Sanitarium and Hospital for Chronic Disease, Brooklyn, N. Y.

development. Pulmonary emphysema was also noted. Admission to this hospital was prompted by continued poor feeding, cough, diarrhea, and failure to gain weight.

The infant was underdeveloped and undernourished and coughed frequently. Ptosis of the right eyelid was present. The lungs were clear to percussion and auscultation. The heart was slightly enlarged. There was a Grade 2 systolic murmur over the precordium and a diastolic murmur at the pulmonic area. Deep cyanosis was not present, but there was a cerise color of the lips and slate-gray color of the skin. Clubbing was absent. The liver was just palpable. A pilonidal sinus was present.

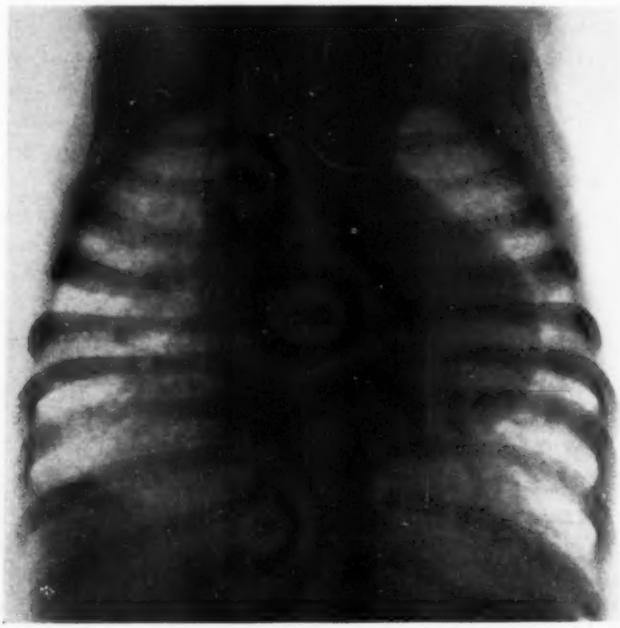

Fig. 1 (Case 1).—Enlargement to the left with marked rounding of the apex. Pulmonary markings are distinct. Bilateral infiltrations, more marked on the right.

The hemoglobin was 14.5 Gm. per 100 c.c. of blood. The red cell count was 4.5 million per cubic millimeter of blood. The roentgenogram (Fig. 1) showed that the heart was enlarged, predominantly to the left, with marked rounding of the apex. The pulmonary markings were distinct. Evidence of emphysema was present. There were indications of pulmonary infiltrations bilaterally, most marked on the right side. The electrocardiogram (Fig. 2) was read as follows: "Sinus tachycardia, rate 150 per minute. Peculiar axis deviation, with a biphasic QRS in Lead III preceded by a small R. Small Q_1 and S_1 are present. P_2 is peaked and prominent. T_2 and T_3 are inverted. The QRS complex in CF_1 is of high voltage and biphasic. The T-wave changes may be suggestive of cardiac hypertrophy. The P-wave changes may be seen in atrial hypertrophy."

The infant failed to gain weight. Feedings were regurgitated; dehydration necessitated the use of clyses. On the twenty-fourth hospital day, sudden death occurred.

Principal Findings at Post-Mortem Examination.—The body was poorly developed and poorly nourished. There was slight cyanosis of the lips. The skin and oral mucosa were very pale. There was no vaginal opening in the vulva. No clubbing of the fingers or toes was noted.

Abdomen: There was abnormal mobility and torsion of the entire small bowel because of a maldeveloped mesentery.

Thorax: The lungs were voluminous. The mediastinum was wider than normal because of conspicuous cardiac enlargement. The cardiac apex was at the left anterior axillary line.

Heart: The heart was enlarged and had an unusual configuration. The apex was rounded. The right border was formed by the right atrium, the left by the left ventricle. At the base of the heart, two large arteries arose side by side. The artery to the right was the aorta; it gave rise to a short innominate artery (which divided into right subclavian and carotid) and then, in the usual order, to the left carotid and left subclavian arteries. Between the aorta and the pulmonary artery there was a patent ductus arteriosus. Distal to the ductus, the aorta became markedly narrowed, and then widened in its thoracic portion. The right atrium received a right innominate

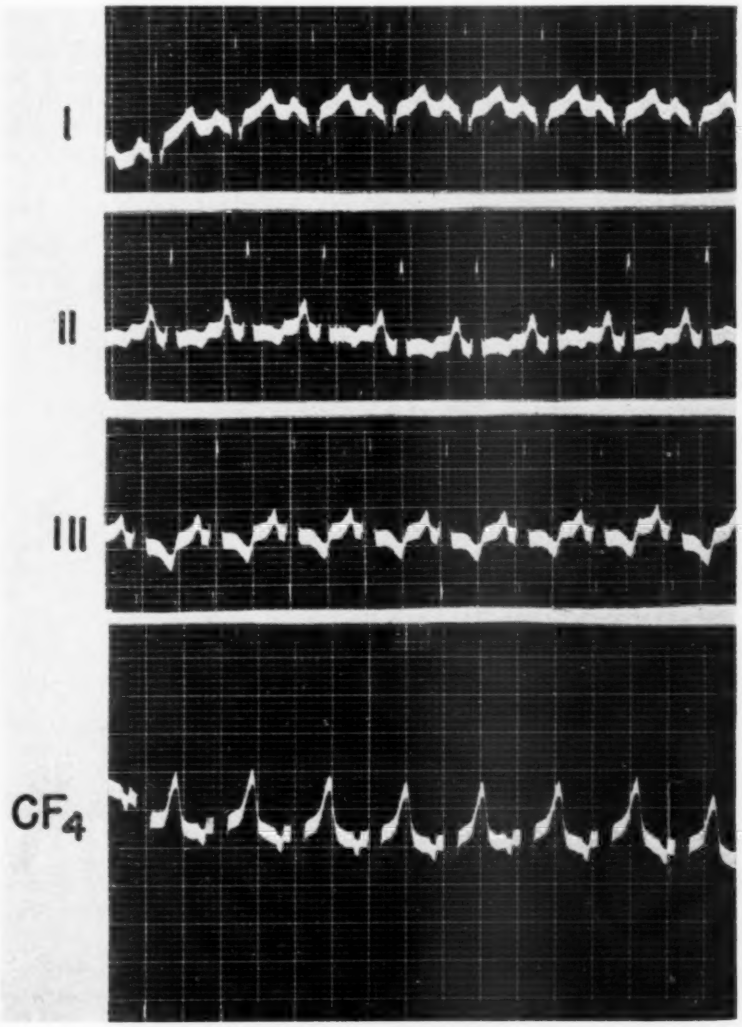

Fig. 2 (Case 1).—Unusual axis deviation. Tall R′ greater than S in Lead III. P_2 is peaked.

vein and the left atrium a left innominate vein. There was no superior vena cava. The inferior vena cava entered the right atrium in the normal manner. The right atrium was wide and showed three outpocketings communicating with the atrium through narrow openings. One of these had the structure of an atrial appendage, and it was compressed by the two large arteries. The other two pockets were anterior and produced an indentation between the two ventricles.

The right atrium communicated with the smaller left atrium through a widely open ostium primum about 1.3 cm. in diameter. The left atrium received one right and two left pulmonary

veins and lay posterior to the left ventricle. The tricuspid valve was absent. The mitral valve consisted of three well-formed cusps, attached by strong chordae to three short, round papillary muscles.

The left ventricle had a thick muscular wall, varying from 5 mm. to 1.0 cm. Its shape was that of a muscular, curved tube with a posterior inflow and an anterior outflow tract. The most inferior portion of the curve formed the apex. The pulmonary artery arose from the left ventricle and was slightly wider than the aorta. The pulmonic valve had three well-formed cusps. From the main pulmonary trunk arose first the right pulmonary artery, then the ductus arteriosus, and then the left pulmonary artery.

At the base of the interventricular septum there was a defect measuring 5 mm. in its longest diameter. The defect led into a small anterior right ventricle and constituted the only communication of this chamber with the other chambers of the heart. The right ventricle had a short narrow cavity, and its wall was only 3 to 4 mm. thick. From this ventricle arose the transposed aorta. The aortic valve had three well-formed cusps and wide bulging sinuses of Valsalva. There were two coronary ostia and normal coronary arteries.

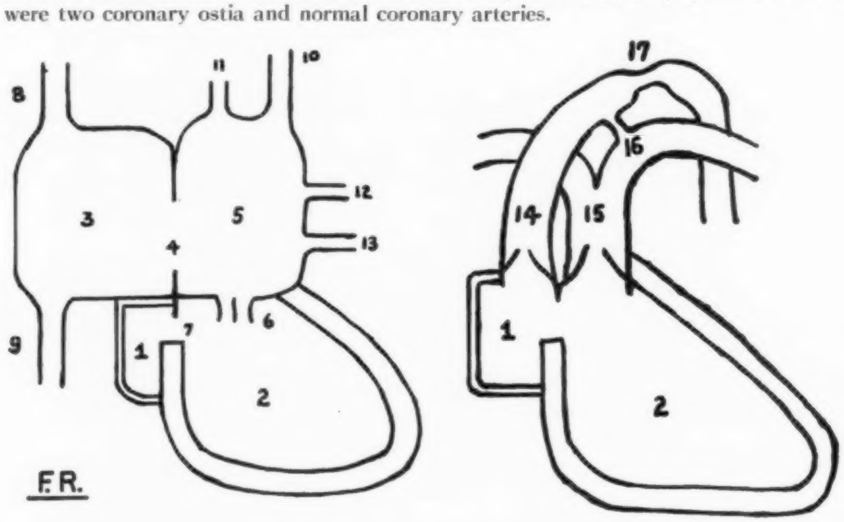

Fig. 3.—Diagram of circulation in F. R.: *1*, **hypoplastic right ventricle;** *2*, **hypertrophied left ventricle;** *3*, **hypertrophied and dilated right atrium;** *4*, **ostium primum;** *5*, **left atrium;** *6*, **tricuspid mitral valve;** *7*, **interventricular septal defect;** *8*, **right innominate vein;** *9*, **inferior vena cava;** *10*, **left innominate vein;** *11*, *12*, *13*, **pulmonary veins (two left, one right);** *14*, **transposed aorta arising from hypoplastic right ventricle;** *15*, **transposed dilated pulmonary artery;** *16*, **patent ductus arteriosus;** *17*, **coarctation of aorta.**

Lungs: There was pronounced increase of aeration except for a few depressed areas of atelectasis. The vascular markings were prominent. A considerable amount of pale, frothy fluid escaped from all parts of the lung and filled the bronchi.

Genitourinary Tract: The kidneys were small. Together they weighed 15 grams (normal 50 grams). They were normal in gross structure. The ureters and bladder were normal. The uterus was represented by a small, fibrous body to which a tube was attached on each side. There was no endometrial cavity or cervix. The vagina was absent. The ovaries were normal.

Gastrointestinal Tract: There were congestion and focal hemorrhages. Aside from congestion, the liver, gall bladder, spleen, pancreas, and adrenals were normal.

Diagnosis.—The diagnosis was:

1. Congenital heart disease (Fig. 3): (a) tricuspid atresia with complete transposition of the great vessels; (b) persistent ostium primum; (c) tricuspid mitral valve; (d) interventricular septal defect; (e) dilatation of the pulmonary artery; (f) patent ductus arteriosus; (g) coarctation of the aorta; and (h) absence of the superior vena cava

2. Pulmonary emphysema, focal atelectasis, and pulmonary edema
3. Congestion of liver and intestinal tract
4. Malrotation of the small intestine
5. Congenital absence of vagina and uterus.

Comment.—Since cyanosis was mild and the electrocardiogram did not show left axis deviation, the diagnosis of tricuspid atresia was not made during the patient's life. As is so often the case in infants with congenital heart disease and cardiac enlargement, the clinical picture was characterized by pulmonary infections, atelectasis, and emphysema. Poor growth and undernutrition were probably consequences of the poor peripheral circulation which made survival impossible despite good pulmonary flow and oxygenation. The red blood cell count and hemoglobin were normal.

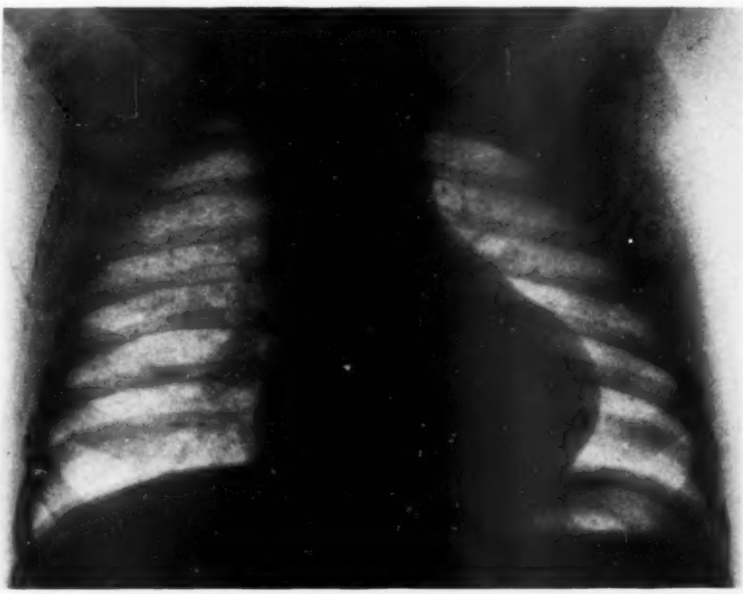

Fig. 4 (Case 2).—Slight enlargement to the left with rounding of the apex. Pulmonary markings are distinct.

The interventricular defect, which had a diameter of 5 mm., was in effect an obstacle to the flow of blood from the left ventricle into the aorta. The compensatory value of the ductus arteriosus is questionable in view of the coarctation of the aorta distal to the ductus. It is obvious that an aortopulmonary shunt (Potts) in a case like this might increase the blood flow into the peripheral vessels from the pulmonary artery where the flow is more than adequate because of the transposition of the great vessels.

CASE 2.—R. B., a white, male infant 5 months old, was admitted to the hospital because of cyanosis and episodes of dyspnea. Pregnancy and delivery had been normal. The attacks of dyspnea and cyanosis were related to the effort of feeding or the passage of stools. These attacks had become fewer as the infant grew older.

The infant was well developed and well nourished. Cyanosis was present and increased during crying or feeding. The lungs were clear to percussion and auscultation. The heart was slightly enlarged to the left. A short, high-pitched, blowing systolic murmur was heard at the third intercostal space just to the left of the sternum. The liver edge was felt 2 cm. below the right costal margin. The left thumb was small; its distal phalanx was angulated laterally.

The red blood cell count was 8.18 million per cubic millimeter of blood, and the hemoglobin was 16 Gm. per 100 c.c. of blood. The urine was normal.

The roentgenogram (Fig. 4) showed that the heart was slightly enlarged to the left. The apex was rounded. The pulmonary markings were distinct.

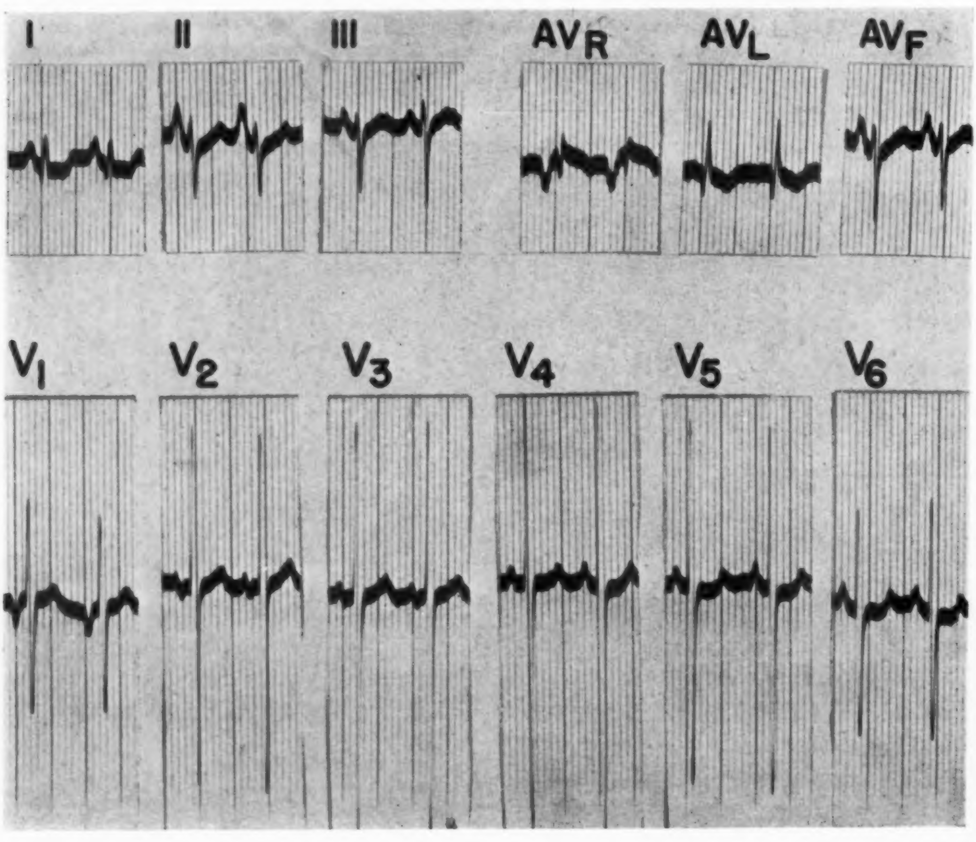

Fig. 5 (Case 2).—Left axis deviation. P_2 is peaked and prominent; aV_L shows positivity. Precordial leads are not characteristic of left ventricular hypertrophy.

The electrocardiogram (Fig. 5) was read as follows: "*Standard leads*: Sinus tachycardia, rate 150 per minute. Left axis deviation. Small Q_1 is present. S_1 is not present. P_2 is peaked and prominent. T_1 is diphasic. $RS\text{-}T_{1,2}$ is slightly depressed. *Extremity leads*: The aV_L shows a Q-R pattern with an inverted T, and the aV_F shows a small R, deep S. *Precordial leads*: From V_1 to V_6 there are biphasic QRS complexes, with high voltage from V_2 to V_5. The peaked P_2 may be seen in atrial enlargement. The T-wave and RS-T changes may be due to hypertrophy, digitalis, or myocardial damage. The positivity in the left arm lead determines the left axis deviation of the standard leads. There is no distinct evidence for a diagnosis of chamber hyper-

trophy other than the high voltage in the precordial leads, which may be a normal finding in an infant. The left axis deviation and the peaked P waves in the presence of cyanosis suggest tricuspid atresia."

The infant was awaiting angiocardiography, when the sudden onset of fever and diarrhea interrupted an otherwise benign course. The child died despite treatment for dehydration and acidosis.

Essential Findings of Post-Mortem Examination.—The body was that of a 6-month-old infant, 49 cm. long (normal 62 cm.). Marked cyanosis and pitting edema of the neck, chest, abdomen, and lower extremities were present. The abdominal cavity contained 150 c.c. of clear yellow fluid. The liver extended 1.4 cm. below the right costal margin.

The epicardium was normal. The right atrial appendage was markedly enlarged. The superior and inferior venae cavae emptied into the right atrium. The ascending aorta was situated to the right of the pulmonary artery, and both were located markedly to the right of the left anterior descending branch of the left coronary artery. The left ventricle was hypertrophied and dilated, its wall measuring up to 1.0 cm. in thickness. The aorta which was dilated made its exit from the right upper angle of this chamber. The aortic valve was normal. There was an 8 by 3 mm. patency of the upper portion of the interventricular septum. The aorta did not override the septum. The right ventricle was a small cavity which did not communicate with the right atrium because the tricuspid valve was atretic. The right ventricle communicated with a hypoplastic pulmonary artery through a narrow outflow tract just in front of the interventricular septum. The pulmonic valve was normal. The left atrium received four pulmonary veins. It communicated with the right atrium through an interatrial septal defect measuring 1.2 cm. The right atrium was dilated. The pulmonary artery divided normally into right and left branches. There was a common origin of the innominate and left common carotid arteries from the aorta. The ductus arteriosus was patent and measured 3 mm.

Diagnosis.—The diagnosis was:

1. Congenital heart disease (Fig. 6): (a) tricuspid atresia; (b) hypoplasia of right ventricle and pulmonary artery; (c) dilatation of the right atrium with persistent ostium secundum; (d) interventricular septal defect; (e) patent ductus arteriosus, small; (f) hypertrophy of the left ventricle; (g) high origin of the coronary ostia; (h) common origin of the left common carotid and innominate arteries; and (i) dilatation of ascending aorta and aortic arch
2. Mild ascites
3. Acute congestion of left lung, liver, spleen, kidneys, and colon
4. Retarded development; congenital hypoplasia of left thumb.

Comment.—The diagnosis of tricuspid atresia was made ante mortem on the basis of the cardiac configuration, the presence of cyanosis, and the left axis deviation. The elevated red blood cell count and hemoglobin clearly indicated the presence of anoxia. The clinical course was benign until the terminal illness of diarrhea with dehydration and acidosis.

The interventricular defect was large but still constituted an obstacle to the flow of blood from the large left ventricle. The small cavity of the right ventricle and the hypoplastic pulmonary artery were perhaps the chief causes for diminished pulmonary blood flow. The lumen of the ductus was tiny; hence, this vessel could not have been adequate as an aortopulmonary shunt. Despite these obstacles to pulmonary blood flow, enough blood apparently reached the lungs to maintain fair physical development. In this case, a shunting operation (Potts or Blalock) would have augmented the pulmonary blood flow and increased oxygenation, as is the case in tetralogy of Fallot.

DISCUSSION

The anatomical types of tricuspid atresia were classified by Edwards and Burchell[2] as follows:

Type I: No transposition of the great vessels
- A. With pulmonary atresia; closed ventricular septum
- B. With subpulmonary stenosis

Type II: Transposition of the great vessels
- A. With pulmonary or subpulmonary stenosis
- B. Without pulmonary or subpulmonary stenosis.

Types IB and IIB are well illustrated by the two cases in this report.

Fig. 6,*A*.—Anatomical findings in R. B.: *1*, superior vena cava; *2*, hypertrophied and dilated right atrium; *3*, dilated aorta; arrow, hypoplastic pulmonary artery; *4*, hypertrophied left ventricle.

The second case is one of typical tricuspid atresia (Type IB) without transposition of the great vessels and with inadequate pulmonary blood flow due to the rudimentary right ventricle and the markedly hypoplastic pulmonary artery.

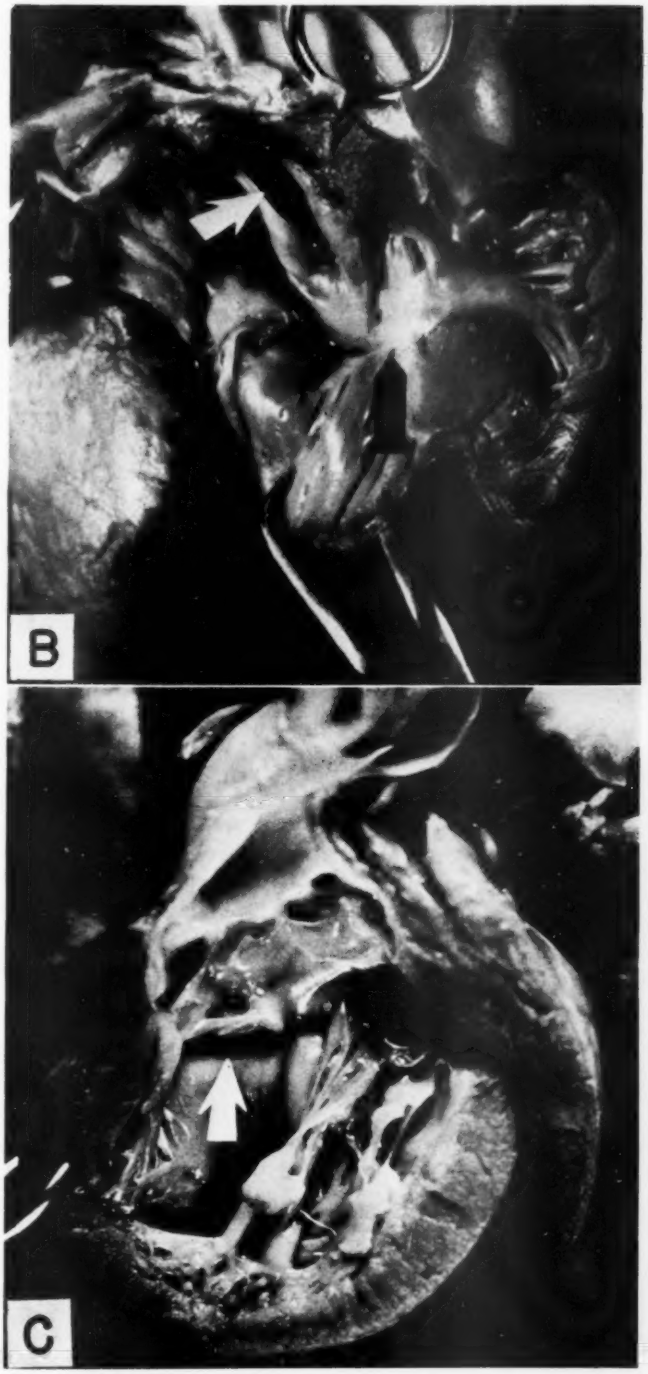

Fig. 6, *B* and *C*.—*B*, White arrow points to interatrial septal defect. The hypertrophied atrial muscle bands radiate from dimple, the atretic tricuspid valve (black arrow). *C*, Hypertrophied and dilated left ventricle; dilated aorta. Arrow points to interventricular septal defect.

This type of lesion, i.e., without transposition of the vessels and with pulmonary stenosis, hypoplasia, or atresia, is represented thirty-three times in the fifty reported cases of tricuspid atresia. These are the cases where the indications for a shunting operation are relatively well defined. Most of these patients die in infancy either because of closure of the ductus arteriosus, because of heart failure, or because of the complications of an intercurrent illness and anoxia. The presence of a patent ductus arteriosus or collateral dilated bronchial arteries may increase the life span but may still fail to provide optimal pulmonary blood flow. However, the presence of a large functioning ductus chiefly in association with complete pulmonary atresia (Type IA) may contraindicate an anastomotic procedure. From the experience in one case, Swan and associates[11] suggest that a marked increase in blood oxygen saturation after the administration of 100 per cent oxygen may be diagnostic of a large ductus with adequate pulmonary blood flow. The presence of a ductus arteriosus or other collateral channels need not, however, contraindicate surgical operation. In the case of Fell and co-workers[4] the aortopulmonary shunt (Potts) apparently functioned in the presence of a ductus arteriosus. In the case of Blumenthal and Brahms[12] the systemic-pulmonary shunt (Blalock) also functioned in the presence of collateral pulmonary circulation.

The first case is a typical example of tricuspid atresia with transposition of the great vessels but without pulmonary stenosis (Type IIB). Tricuspid atresia with transposition of the great vessels may be subdivided into cases with pulmonic or subpulmonic stenosis (Type IIA) and those without obstruction to pulmonary blood flow, as in our Case 1 (Type IIB). The cases of transposition with obstruction to pulmonary blood flow (Type IIA) are physiologically similar from the surgical standpoint to those cases without transposition and pulmonic stenosis (Type IB). An anastomotic procedure may be indicated to increase pulmonary blood flow. However, the cases of tricuspid atresia with transposition of the great vessels and without pulmonary obstruction (Type IIB) are in a different category. There is adequate flow through the pulmonary artery which arises from the left ventricle. In fact, flow may be excessive and lead to pulmonary edema. A shunting operation to increase pulmonary blood flow most certainly is not indicated. However, there is the possibility that an anastomotic procedure might be useful in some of these patients without pulmonary stenosis. Patient F. R. demonstrated obstruction to peripheral blood flow because of a small interventricular defect and chiefly because of a localized hypoplasia of the aorta. Such hypoplasia and coarctations of the aorta are common in the reported cases of tricuspid atresia with transposition of the great vessels and adequate pulmonary blood flow (Type IIB).[3,13-17] It is conceivable that an aortopulmonary shunt in some of these cases might equalize the distribution of blood to the lungs and to the periphery.

The presence of tricuspid atresia is suspected when cyanosis, left axis deviation, and radiological evidence of a hypoplastic right ventricle are found. The roentgenograms of the patients in this report indicate that the presence or absence of lung markings is not a reliable differential point in the diagnosis of transposition of the great vessels without pulmonary stenosis. The lung markings may

not be prominent in transposition without pulmonary stenosis and may be normal when pulmonic stenosis exists, with or without transposition. However, the fluoroscopic observation of pulsating pulmonary vascular shadows may justifiably point to the diagnosis of transposition without pulmonary obstruction. A normal hemoglobin concentration and red blood cell count, as seen in patient F. R., should suggest the absence of pulmonary stenosis.[3] Direct evidence of transposition of the vessels can be obtained by angiocardiography.[12,18] Most of the anatomical details of tricuspid atresia can best be determined preoperatively by angiocardiography and cardiac catheterization.[11,12,19,20] The electrocardiogram of one of our patients, F. R., demonstrates that left axis deviation need not be present in tricuspid atresia.

SUMMARY

1. Two cases of congenital tricuspid atresia with autopsies are presented.

2. The cases illustrate two anatomical types of tricuspid atresia: (a) the more common tricuspid atresia without transposition of the great vessels and with pulmonary stenosis (Type IB), and (b) the rarer tricuspid atresia with transposition of the great vessels and without pulmonic or subpulmonic stenosis (Type IIB).

3. In tricuspid atresia the electrocardiogram need not show left axis deviation.

4. The presence or absence of pulmonary vascular markings is not a reliable differential point in the diagnosis of transposition of the great vessels without pulmonary stenosis.

5. On the basis of the anatomical findings it is suggested that an aortopulmonary shunt (Potts) may be indicated in tricuspid atresia with transposition of the great vessels and without pulmonary stenosis. The anastomotic procedure might equalize the blood flow to the lungs and to the periphery.

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ANOMALOUS PULMONARY VEINS

J. Chandler Smith, M.D.

Chicago, Ill.

Anomalous pulmonary veins are of interest for several reasons. Although these anomalies are rare, the diagnosis can frequently be made with the aid of the angiocardiogram and the cardiac catheter. It is expected that such anomalies will occasionally be encountered during the surgical treatment of congenital heart disease, and cases in adults have been noted during pneumonectomy.[1] It has been suggested that some cases of anomalous pulmonary veins may be amenable to surgical treatment.

CASE REPORT

The patient was a white, male infant, 8 weeks old, who was delivered at full term after a normal pregnancy and an uncomplicated labor. On the day after delivery cyanosis was noted. The infant was given oxygen and penicillin during the next 5 days. The cyanosis disappeared, but a persistent cough developed and the infant seemed somewhat inactive. There was a gain of 2 pounds during the first 2 months of life. Duskiness of the skin was noted on crying, but there was no cyanosis at rest. X-ray and fluoroscopic examinations of the chest at the age of 1 week were normal. The patient was then well until 36 hours before hospital admission when progressive irritability, restlessness, and rapid respirations developed.

The temperature was 37.0° C., pulse 180, and respirations 70 per minute. Physical examination on admission revealed a well-developed, white, male infant who was cyanotic and whose respirations were rapid, shallow, and gasping. The significant physical signs were limited to the chest. The heart was slightly enlarged to percussion. A thrill was not palpated. A harsh systolic murmur heard over the entire precordium was loudest over the third intercostal space close to the left border of the sternum. The right and left lungs were clear to percussion and auscultation. The liver was palpated 2 cm. below the right costal border. The remainder of the physical examination was negative.

Hematologic examination revealed: 12.0 Gm. of hemoglobin per 100 c.c., 3,500,000 erythrocytes and 10,200 leucocytes per cubic millimeter, and a normal differential count. Oxygen was given, but the cyanosis was constant and respiratory difficulty increased. The infant died 8 hours after hospitalization.

Autopsy.—The body was that of a well-developed, white, male infant who weighed 3.9 kilograms and measured 57 centimeters from crown to heel. The heart weighed 46 grams; its expected weight was 23 grams. The epicardium was smooth and glistening. The right atrium and right ventricle were markedly enlarged. Sections revealed a moderately firm, uniformly brownish-red myocardium. The right and left ventricles each measured 0.4 cm. in thickness. The wall of the right atrium was markedly dilated and thickened with prominent pectinate muscles. A persistent septum spurium extended from the posterior wall of the right atrium and partially divided this chamber into 2 compartments (Fig. 1). The superior vena cava entered the right atrium normally. The inferior vena cava opened into the right atrium between the persistent septum spurium and the interatrial septum. The foramen ovale was closed. An interatrial septal defect measuring 0.5 cm. in diameter was present just above the closed foramen

From the Institute of Pathology, Cleveland, Ohio.
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ovale. The coronary sinus opened into the right atrium at the base of the persistent septum spurium. The right ventricle was capacious with blunt, thick, grayish white columnae carneae. The tricuspid and pulmonic valves were normal. The pulmonary artery divided normally, and the branches extended to the right and left lungs. The ductus arteriosus was closed.

No veins entered the small left atrium (Fig. 1). The wall was thin, and the pectinate muscles were barely discernible. The mitral valve was thin, smooth, and translucent. The left ventricle was of normal size, and the aortic valve was normal. The right and left coronary arteries were of normal origin and distribution. The aorta was thin, and the intima was smooth. There was no coarctation, and the ostium of the ductus arteriosus was closed.

Single veins issued from the upper and lower lobes of the left lung and joined to form a common channel which received a large single vein from the lower lobe of the right lung. This common venous trunk emptied into the pulmonary vein which issued from the upper lobe of the right lung, and the latter vessel then directed all venous blood from both lungs into the superior vena cava close to its entrance into the right atrium (Fig. 2).

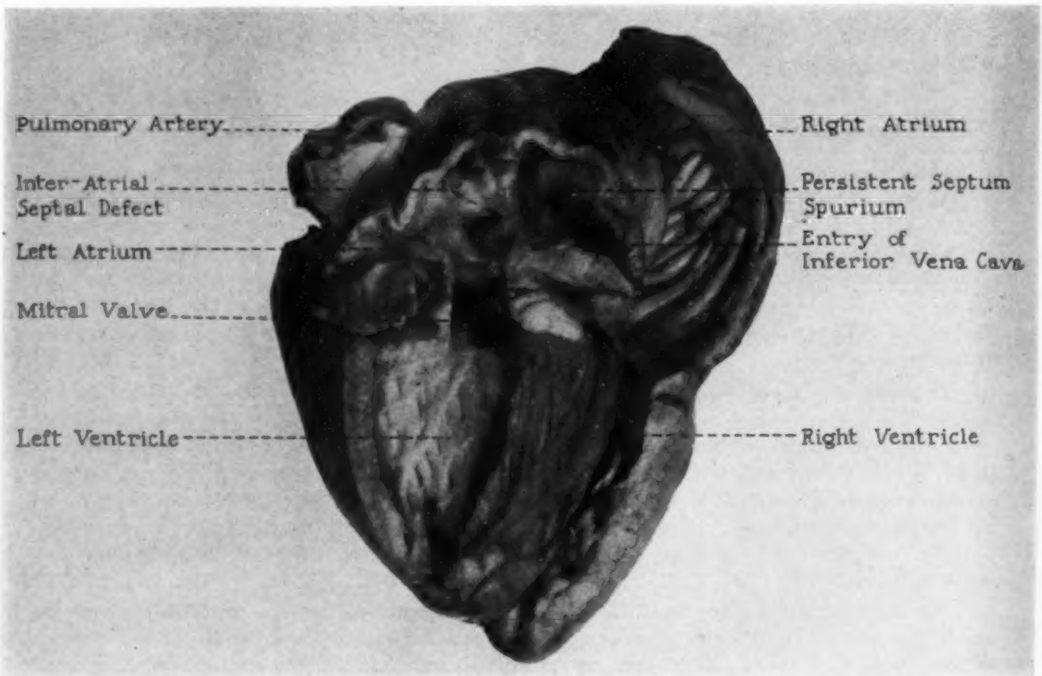

Fig. 1.—Posterior surface of heart with section of the left ventricle cut away. Hypertrophy and dilatation of the right atrium and right ventricle are apparent.

The right and left lungs weighed 54 grams each; the expected weights were 32 and 29 grams, respectively. Petechiae were sparsely scattered in the pleura. The pulmonary tissue was crepitant and of slightly increased firmness. Sections revealed uniformly dark red, moist cut surfaces on which alveolar spaces were barely discernible. The autopsy was limited to the thorax and abdomen, and no further abnormalities were found.

Histologic examination of the myocardium revealed normal muscle. Sections of lung disclosed slight focal atelectasis and edema. The alveolar walls were somewhat thickened, and the capillaries were distended with erythrocytes. Small clusters of erythrocytes and scattered large mononuclear cells with intracytoplasmic brown pigment granules were present within the alveoli. The pulmonary vessels were not abnormal. Histologic examination of the liver revealed slightly

dilated sinusoids throughout the lobules that were for the most part empty. Microscopic examination of the remaining tissue disclosed no further abnormalities.

The pathologic diagnoses included anomalous entry of the right and left pulmonary veins into the superior vena cava with interatrial septal defect and persistent septum spurium. There were hypertrophy and dilatation of the right atrium and right ventricle with closed foramen ovale and closed ductus arteriosus. Chronic passive hyperemia of the lungs with focal atelectasis and slight focal pulmonary edema were present.

DISCUSSION

Winslow, in 1739, is credited with the first report of a case of anomalous drainage of pulmonary veins.[2] Since that time, many cases have been recorded, and in 1942, Brody, in a thorough search of the literature, was able to find 102 cases to which he added 4 others.[3] Brody classified these cases into 3 types.

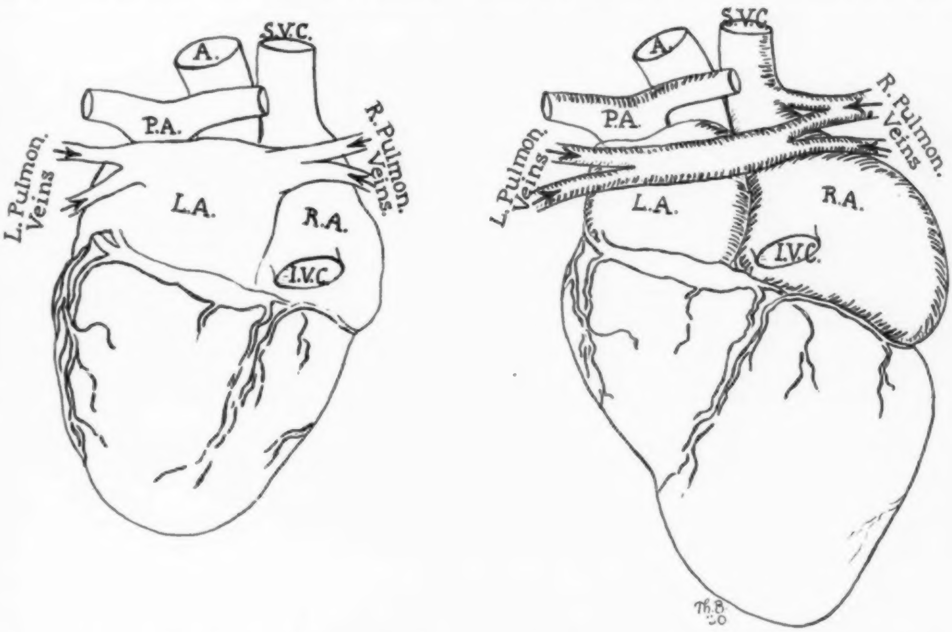

Fig. 2.—Left: posterior surface of heart showing normal relationships of pulmonary veins. Right: posterior view of heart showing common pulmonary vein opening into superior vena cava.

The first type included those patients in whom some of the pulmonary veins drained into the right atrium or its tributaries. The second type included those patients in whom all of the pulmonary veins emptied into the right atrium or the veins leading into it. The third type was similar to the second, but, in addition, there were other anomalies of the cardiovascular system. Several descriptions of anomalous pulmonary veins have appeared since the paper of Brody, but these have not been assembled in a single report. Tables I, II, and III present the cases of anomalous pulmonary veins not mentioned by Brody and those recorded since his paper in 1942.

During early embryologic development, a common pulmonary vein opens into the dorsal wall of the sinus venosus. The opening of this vein normally

shifts to the left at the time of formation of the interatrial septa. As the left atrium enlarges, the sinus venosus is incorporated into the wall of this chamber. The pulmonary vein is also drawn into the left atrial wall beyond the first division of each primary branch so that with full development 4 separate pulmonary veins enter the left atrium. Although the precise embryologic fault which results in misplacement of pulmonary veins into the right atrium or its tributaries is not known, it is widely held that an important factor in many cases is a faulty shift of the common pulmonary vein ostium at the time of formation of the interatrial septa. Other concepts are discussed by McManus,[4] and investigations of the origin and development of the pulmonary veins in animals are reported by Brown[5] and by Buell.[6]

Including the present case, there are now 133 reports of anomalous drainage of pulmonary veins on record. In 75 of these, part of the pulmonary veins emptied into the right atrium or its tributaries, and in 56 all of the pulmonary veins drained into the right atrium or the veins leading into it. In the case of Sömmering and the case of Turner, as cited by Hughes and Rumore,[7] insufficient data precluded classification.

TABLE I. INCOMPLETE DRAINAGE OF PULMONARY VEINS INTO RIGHT HEART

AUTHOR	SEX	AGE	DRAINAGE INTO	FORAMEN OVALE	DUCTUS ARTERIOSUS	COMMENT
Töply	M	20 yr.	Superior vena cava			Lobar pneumonia
Heller			Superior vena cava			
Konaschko	M		Superior vena cava			
Hughes and Rumore[7]	M	55 yr.	Superior vena cava	Closed	Closed	Rheumatic heart disease
Hughes and Rumore[7]	M	44 yr.	Left innominate vein	Closed	Closed	Rheumatic heart disease
Compere and Forsyth[18]	M	48 yr.	Superior vena cava	Closed	Closed	Cerebral syphilis
Conant and Kurland[22]	M	37 yr.	Left innominate vein	Closed	Closed	Bilateral pulmonary tuberculosis

There are now on record 75 cases of partial drainage of pulmonary veins into the right atrium or its tributaries. The structures into which part of the pulmonary veins emptied included the superior vena cava (35 cases), the right atrium (18 cases), and the left innominate vein (16 cases). Less common sites included the coronary sinus, the inferior vena cava, the azygos vein, and the left subclavian vein.

According to Brody, the right pulmonary veins were displaced twice as frequently as the left.[3] Of the reports in which sex was stated, there were 30 male and 11 female patients. The ages varied from less than 1 year to 86 years. However, most were healthy adults, and signs of cardiac decompensation were uncommon. Brody stated that cardiac decompensation was unlikely if less than 50 per cent of the pulmonary venous blood was delivered into the right atrium. The condition is usually not productive of symptoms, although Taussig[8] pointed out that slight enlargement of the right ventricle and fullness of the pulmonary conus may be demonstrated by fluoroscopic examination. The condition should

be considered when the oxygen content of blood aspirated from the right atrium through the cardiac catheter is higher than that of venous blood from the arm. The anomaly would assume importance in a patient with left pneumonectomy in whom the right pulmonary veins emptied into the superior vena cava or right atrium. Life could then be sustained only by an interatrial septal defect or patent ductus arteriosus through which pulmonary venous blood could gain access to the systemic circulation.

TABLE II. COMPLETE DRAINAGE OF PULMONARY VEINS INTO RIGHT HEART

AUTHOR	SEX	AGE	DRAINAGE INTO	FORAMEN OVALE	DUCTUS ARTERIOSUS	COMMENT
Conn and associates[17]		7 days	Superior vena cava	Open	Closed	
Didion[16]	M	4 mo.	Right atrium	Open	Closed	Dilated pulmonary artery
Didion	M	4 mo.	Left innominate vein	Open	Closed	Persistent left superior vena cava
Didion	F	1 mo.	Left innominate vein	Open	Closed	Persistent left superior vena cava
Merkel[15]	M	25 days	Right atrium	Open	Closed	
Graham[19]	F	8 mo.	Right atrium	Open	Closed	
Kernan[20]	M	4 mo.	Left innominate vein	Open	Closed	Persistent left superior vena cava
Mykschowsky[23]	M	18 days	Portal vein	Open	Closed	
Edwards and Du Shane[21]		9 days	Ductus venosus	Open	Closed	

With the present case and the cases collected by Brody,[3] there are now 33 published reports of complete drainage of pulmonary veins into the right atrium or its tributaries that are not associated with other major anomalies of the cardiovascular system. Sex was stated in 29, and these included 18 male and 11 female patients. The structures into which all of the pulmonary veins emptied included the superior vena cava (9 cases), the coronary sinus (7 cases), the right atrium (6 cases), the left innominate vein (3 cases), and the portal vein (2 cases). In 1 case each, all of the pulmonary veins emptied into the inferior vena cava, the portal vein, and the ductus venosus. Most of the hearts disclosed hypertrophy and dilatation of the right atrium and right ventricle, and in many a small left ventricle was described. Only 5 patients lived beyond the age of 8 months.

There is no circulatory impairment during intrauterine life in cases of complete drainage of pulmonary venous blood into the right atrium. Aerated blood entering the right heart through the inferior vena cava from the umbilical vessels is shunted into the aorta through the ductus arteriosus, and pulmonary venous blood entering the right atrium from the lungs is directed into the left atrium through the patent foramen ovale. At birth, however, when pulmonary oxygenation is required, venous blood from both the systemic and pulmonary circuits enters the right atrium and is propelled into the lungs through the pulmonary artery. This cycle recurs, and, as the ductus arteriosus gradually closes, the foramen ovale remains as the only aperture between the systemic and pulmonic

circulations. Although its function is compensatory, the foramen ovale tends to close,[8] and death ensues with blockage of this last connecting channel.

Patients with complete drainage of pulmonary venous blood into the right heart are characterized clinically by normal development during the first and second months of life, after which progressive enlargement of the right heart and dyspnea without cyanosis are noted. Murmurs may be absent, although a harsh systolic murmur over the apex is not unusual and this is ascribed to passage of blood through the foramen ovale. X-ray examination usually reveals cardiac enlargement to the right, and the electrocardiogram frequently discloses evidence of right heart strain. Chest roentgenograms after intravenous injection of radio-opaque dye may reveal dilatation of the superior vena cava or an abnormal venous channel entering the right atrium.

The oxygen saturation of blood removed from the right atrium through the cardiac catheter is equal to that of peripheral arterial blood. Taussig considers this pathognomonic of complete drainage of pulmonary veins into the right atrium.[8]

The condition is simulated clinically by pulmonic stenosis and interatrial septal defect. Although enlargement of the right heart with minimal cyanosis is characteristic of isolated pulmonic stenosis, signs of pulmonary congestion are rare. In patients with interatrial septal defect, the oxygen saturation of blood in the right atrium is always lower than that of blood in the peripheral arteries.

Brantigan[1] suggested removal or enlargement of the interatrial septum or anastamosis of a pulmonary vein to the left atrium as treatment for this anomaly. No such undertaking has been reported, and of the 33 patients with complete drainage of pulmonary venous blood into the right atrium not associated with other anomalies, only 5 lived beyond the age of 8 months.

TABLE III. COMPLETE DRAINAGE OF PULMONARY VEINS INTO RIGHT HEART WITH OTHER ANOMALIES

AUTHOR	SEX	AGE	DRAINAGE INTO	FORAMEN OVALE	DUCTUS ARTERIOSUS	COMMENT
Michaelsohn[9]	M	21 yr.	Left superior vena	Open		Cor biloculare
Spitzer[10]		5 mo.	Superior vena cava	Open		Interatrial septal defect
Barge and van Oijen[12]	F	4 mo.	Superior vena cava			Atrioventricularis communis
Ingals	F	2 mo.	Superior vena cava	Open	Open	Dextrocardia
Feldman and Chalmers[13]	M	2 mo.	Right atrium	Open	Closed	Transposed great vessels
Goltman and Stern[14]	M	14 mo.	Superior vena cava	Open		Truncus arteriosus
Young[21]		6 mo.	Portal vein	Open	Open	Cor triloculare biatriatum
Mehn and Hirsch[2]	M	12 days	Ductus venosus	Open	Closed	Coarctation of aorta

There are now 23 reported cases, including those collected by Brody,[3] in which complete drainage of pulmonary veins into the right heart was associated with other significant anomalies of the cardiovascular system. Sex was stated in only 15, and these included 9 male and 6 female patients. The additional

anomalies included cor biloculare, defects of the interatrial and interventricular septa, transposition of the great vessels, cor triloculare biatriatum, and atresia of the pulmonic artery and aorta. The structures into which the anomalous pulmonary veins drained included the right atrium, the superior vena cava, the portal vein, and a persistent sinus venosus. In these patients, an anomaly of the cardiovascular system was usually clinically apparent at birth or soon after birth. Most of these patients died in early infancy, although 4 lived beyond the age of 6 months. However, 2 of these patients had essentially single atrium hearts that permitted mixing of the blood from the systemic and pulmonic circulations.

SUMMARY

The literature now embodies 133 case reports of anomalous drainage of pulmonary veins. Of these patients, partial drainage into the right atrium occurred in 75, and complete drainage into this chamber or its tributaries occurred in 56. Additional cardiovascular anomalies were present in 23 of the latter group of patients. Partial drainage of pulmonary veins into the right atrium is consistent with long life. In 56 reported cases of complete drainage of pulmonary veins into the right atrium, only 10 patients lived beyond the age of 8 months. The clinical diagnosis of complete drainage of pulmonary veins into the right atrium can be established by use of the cardiac catheter and the angiocardiogram. An additional case is described in which all of the pulmonary veins emptied into the superior vena cava in a male infant who lived to the age of 8 weeks.

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THE ACTIVATION OF THE INTERVENTRICULAR SEPTUM

Dedicated to Frank N. Wilson

DEMETRIO SODI-PALLARES, M.D., MARÍA ISABEL RODRIGUEZ, M.D., LEONARDO O. CHAIT, M.D., AND RUDOLF ZUCKERMANN, M.D.

MEXICO, D.F.

WE OWE credit to Sir Thomas Lewis[1,2] for the major contributions to the understanding of the process of activation in the mammalian heart. His studies have revealed the importance of the bundle of His, its branches, and the fibers of Purkinje in the process of activation. These facts can be considered fundamental in modern electrocardiography.

The time of arrival of the activation wave at the epicardial surface of the free ventricular walls can be studied with relative ease by using the different types of leads available. On the other hand, the same study in the interventricular septum is a difficult matter. Lewis pointed out the difficulties of controlling the position of the electrodes and obtaining satisfactory electrograms.

Lewis and Rothschild,[1] as reported in their excellent paper on the excitatory process in the dog's heart, placed leads on the septal aspects and were thus able to relate the intrinsic deflections of these leads to the beginning of the R wave in Lead II.

They found that on the right aspect of the interventricular septum the activation wave arrives first at the base of the anterior papillary muscle. The intrinsic deflection clearly precedes the beginning of R in Lead II (values of 0.0082, −0.008, and 0.0039 second, the negative sign indicating that the corresponding intrinsic deflection was recorded before the beginning of R in Lead II).

In the middle regions of the septum, the results were variable, from 0.0033 to 0.0060 second; in the upper regions higher values were encountered, from 0.0144 to 0.0243 second. According to the authors, "these last values are very high, but not incompatible with the anatomical conditions. It will be remembered that Purkinje fibers in the neighborhood of the septal cusp of the tricuspid valve are apparently sparse or absent, and this is the region upon which the contacts lay."

In the middle regions of the left aspect of the septum, the results were also variable (−0.0036, −0.0085, and 0.0066 second). In two animals values could be obtained immediately below the aortic valves that were −0.0168 and −0.0022 second. The authors said: "The former is the lowest reading we have obtained from any part of the heart. This is of interest since from the distribution of Purkinje substance this is the region where we should expect earliest activity. Directly below the valves the left division of the bundle appears and the re-

From the Department of Electrocardiography of the Instituto Nacional de Cardiologia de México.
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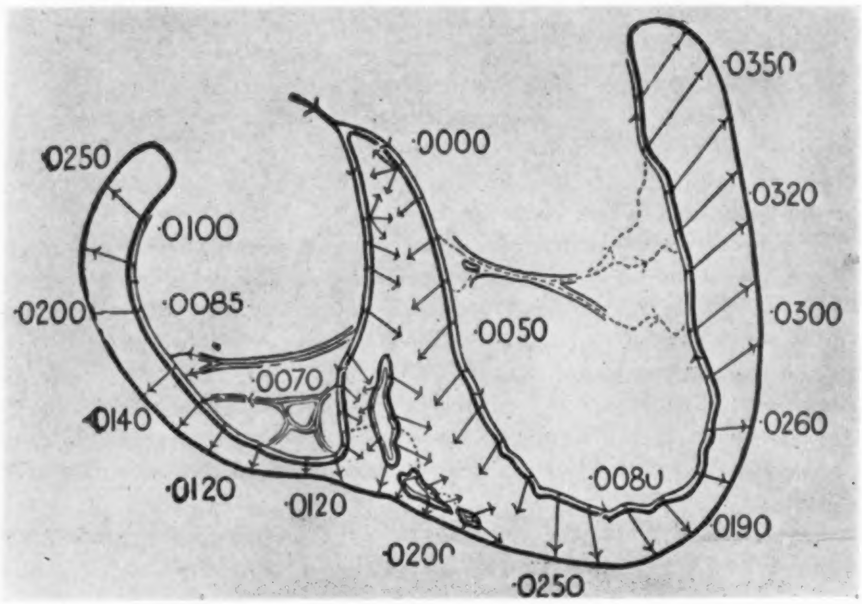
branching begins almost immediately. But there are small areas close at hand which appear to have little or no supply. Very low values and considerably higher values would be anticipated in this neighbourhood."

However, in Lewis' book[2] one finds a scheme of activation (scheme 1) and the following statement: "On both sides the excitation wave spreads first into the septum, moving down and towards right on the left side, and towards the left on the right side; later it moves directly downwards at the apices of the ventricles . . . ."



Scheme 1.—Taken from Lewis.[2]

Before Lewis, other authors had studied the process of activation in the heart of the dog, but very few spoke of the process of activation in the interventricular septum. Nevertheless, Saltzman,[3] in 1907, said that in the septum the activation proceeded from the base to the apex. Hoffman,[4] in 1910, wrote that the regions activated first corresponded to the base of the papillary muscles. He believed, also, that the regions proximal to the apex were electronegative in relation to the base. According to Schneiders,[5] the activation entered from below upward, both in the septum and in the papillary muscles.

Taking into account the existing discrepancies, we intended to study the activation process of the interventricular septum in the heart of the dog before and after sectioning the branches of the bundle of His.

METHOD

One hundred dogs were used weighing between 10 and 20 kg. They were anesthetized with Nembutal (40 mg. per kilogram). The chest was opened under artificial respiration.

The electrodes used (designed by J. J. Mandoki*) were of two types. The first (Fig. 29) consisted of a steel wire, 7 cm. long and 0.6 mm. in diameter, attached on its distal portion to a small cone of insulating material (lucite). The wire penetrated the base of the cone through its center. A covering of lac insulated the wire in its length, except in an area of 2 mm. square placed directly behind the conical portion. This area constituted the contact of the lead. In cases of unipolar and bipolar distant leads this type of electrode is useful. When leads were taken from two very close regions (proximal bipolar leads), electrodes of the second type were used, which were just a modification of those described above. They consisted of two insulated, parallel wires of the same material and dimensions as the others and separated from each other by a distance of 0.5 mm. Both wires were attached at their distal ends to a single cone of lucite. The lead points, placed at 1.5 mm. distance from each other, were similar to those described for the first type of electrodes.

To explore the right septal surface of the interventricular septum, the electrodes were introduced through the free wall of the left ventricle and left cavity and across the interventricular septum from left to right until the distal extremity of the electrode was in the right ventricular cavity. A slight pull on the electrode was then made, resulting in the placement of the lead point in contact with the right septal surface. Due to the form of its terminal portion, the electrode remained fixed even with changes in the position of the heart. In the same way, the left septal surface was explored, the electrode being introduced through the right ventricular wall and across the right cavity and the whole septum.

The position in which the heart was maintained varied according to the septal aspect to be explored. Thus, to study the left side of the septum, the heart was placed in slight clockwise rotation. This permitted a better exposure of the place of introduction of the electrodes. An opposite rotation was made in order to study the right surface of the septum.

On many occasions, we were able to verify that the electrode did not cross the whole septum, thus recording from different sites within the septal thickness.

The tracings were obtained with four simultaneously recording galvanometers of direct inscription (Poly-Viso Cardiette). The synchronism of the inscribing needles was verified at the beginning and at the end of each experiment. On occasions, the needles were slightly asynchronous, but they did not vary during the course of the experiment. In these cases the calibration control is shown for the corresponding tracings.

Three standard leads were taken before and after applying the electrodes to the septum in order to control the appearance of blocks on the branches of the bundle of His, as occurred in some cases. In general, the introduction of the electrodes did not elicit any changes in the control tracings. Three points were explored in the majority of the experiments, and only in the larger dogs was it possible to place a greater number of electrodes.

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*From the Department of Physiology of the Instituto Nacional de Cardiología de México.

Three types of leads were used:

1. Unipolar Leads.—The unipolar leads of each of the regions studied were recorded simultaneously with one standard lead, generally Lead II. In practically all the experiments there was a certain degree of positive displacement of the RS-T segment, but much less than we expected with this type of lead. Moderate displacements of the RS-T segment did not change the relations between the inferior vertex of the intrinsic deflection and the simultaneous standard lead. Basing our choice on the theoretical discussions of Wilson and his collaborators[7] and on the experimental work[8] undertaken in our department, we took this vertex (the end of the intrinsic deflection) as the point of reference for the arrival of the activation wave at the site of the lead. We believe that, in most instances, these leads are entirely satisfactory, but in some they are not adequate for measuring the time of arrival of the impulse. In these latter cases, we prefer bipolar leads, as will be described. The values given for these leads almost always coincided with those furnished by the bipolar leads with contiguous electrodes. When the unipolar tracings were polyphasic, the last descending line of rapid inscription was considered as the intrinsic deflection; when proximal bipolar leads were employed in the same experiment, the correctness of this criterion was verified. For these measurements, preference was always given to the proximal bipolar leads over the unipolar leads.

On the other hand, the unipolar leads were more useful for determining whether the explored points depended electrically on the left or on the right branch. The bundle branch block modified frequently and to a considerable extent the tracings obtained through proximal bipolar leads with contiguous electrodes, thus making their interpretation very difficult.

2. Bipolar Leads With Contiguous Electrodes.—Each one of the wires of the electrode described for this type of lead was connected to the system, the polarity having no importance since what is desired on these tracings is the time of appearance of the main deflection, be it positive or negative. Generally, three bipolar leads of this type were taken simultaneously and on occasions related to Lead II.

We considered this type of lead the most adequate for determining the arrival of the activation wave at the explored point, since it registered differences of potential between two proximal regions, and the extrinsic factors were reduced better than with other kinds of leads. Notwithstanding this, with the appearance of bundle branch block, the tracings may sometimes be considerably distorted, suggesting the existence of extrinsic factors.

In these leads basing our choice on the works already mentioned,[7,8] we have considered the vertex of the maximum positive or negative deflection as a point of reference for measuring the time of arrival of the excitation wave.

3. Bipolar Leads With Distant Electrodes.—As we have stated, generally three septal points were explored: (1) close to the apex, (2) close to the base, and (3) intermediate between 1 and 2. On these points three bipolar leads were obtained that we call distant because they record differences of potential of two regions separated from each other by several centimeters. In all of these, the

positive electrode of the system was always connected to the upper region, and thus three simultaneous records could be taken. In Lead I of the system, the positive electrode (LA) is connected to the intermediate point and the negative (RA) to the point proximal to the apex; in Lead II the positive electrode (LL) is connected to the basal point and the negative electrode (RA) to that proximal to the apex; in Lead III the positive electrode (LL) is connected to the basal point and the negative electrode (LA) to the intermediate point. It was supposed that if the general process of activation proceeds from the apex to the base of the septum, positive deflections ought to be registered on the three leads and negative deflections in the opposite case.

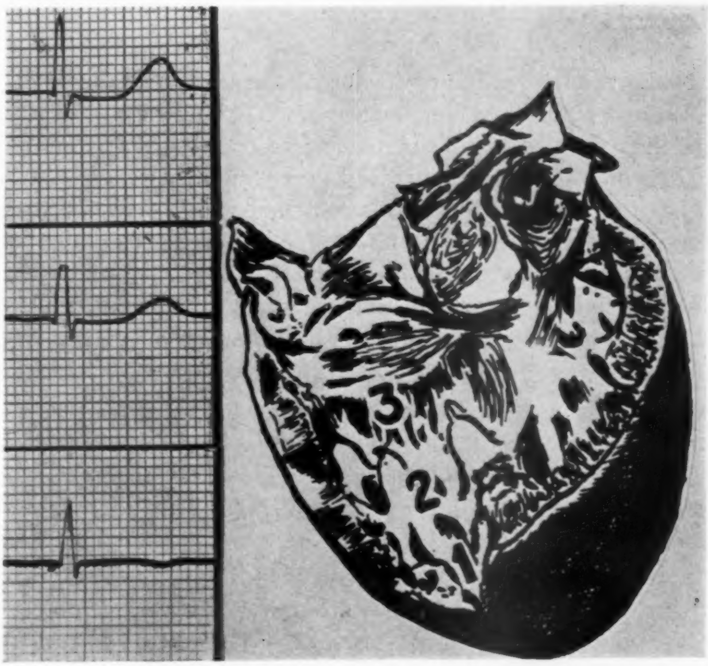


Fig. 1.—Tracings obtained with distant bipolar leads (see method) on the right septal aspect. The lowest electrode (point *1*) was located very close to the apex of the right ventricle. The electrode corresponding to point *2* was placed near the base of the anterior papillary muscle, and electrode *3* was placed below the tricuspid valve. In all the tracings the rapid ventricular deflections are mainly positive.*

We studied the time of arrival of the activation wave and the morphology of the unipolar tracings before and after blocking the branches of the bundle of His. The technique for producing these blocks has been described in former papers.[9,10] By using the bipolar leads with distant electrodes, the extrasystoles induced by mechanical excitation on the epicardial surface of the free ventricular walls were also studied.

*In all the figures presenting bipolar leads with distant electrodes, the upper tracing is taken between points *2* and *1*, the middle tracing between points *3* and *1*, and the inferior tracing between points *3* and *2*.

Since interpretation of the tracings obtained in tissues having partial injuries is difficult and subject to error, it was necessary to perform a great number of experiments. Those results which could be repeated systematically were taken into account.

RESULTS

1. Distant Bipolar Leads.—The results obtained from the bipolar leads with distant electrodes were uniform; in all cases in which the electrodes were properly placed, rapid ventricular complexes, essentially positive, were obtained in all three leads (see method). This suggests that the process of activation in the septum proceeds mainly from below upward. When the tracing was predominantly negative in some of the leads, it was due to the bad placement of an electrode in regard to the other two.

In Fig. 1, the tracings obtained in one of the experiments corresponding to the right septal aspect are shown; it can be seen that the vertex of the major deflection was delayed on the inferior tracing recorded from points *3* and *2* (see the adjoining scheme) and that the earliest vertex was the one on the upper tracing recorded from points *2* and *1*. This sequence suggests also that the activation proceeded mainly from below upward. It should be remembered, however, that this type of lead is not useful for measuring the arrival of the impulse at a certain point. It only indicates the main direction in which activation proceeds.

In Fig. 2, *A*, similar leads obtained on the left septal surface are shown. The rapid deflection was mainly positive in the three tracings.

In order to obtain more information regarding the general direction in which an impulse is propagated in the septum, ventricular extrasystoles were studied, attention being given to the relative predominance of positivity and negativity of QRS in these abnormal complexes. In all cases extrasystoles were elicited at the apex and at the base of the free ventricular walls.

In Fig. 3, the distant bipolar leads corresponding to the regions of the right septal aspect are shown on the adjacent scheme. The ventricular extrasystoles shown in *A* and *C* were initiated at the apex of the right (*A*) and the left (*C*) ventricles. The corresponding tracings show rapid ventricular complexes which were positive. At *B* and *D* the extrasystolic complexes were predominantly negative and were elicited at the base of the right ventricle, close to the pulmonary conus (*B*) and at the basal and lateral parts of the free wall of the left ventricle (*D*).

In Fig. 4, the same type of leads was taken also from the right septal aspect at the points shown on the adjoining figure. At *A* of the same figure, the extrasystoles were predominantly positive and were initiated in the apex of the left ventricle. At *B*, the extrasystolic complexes, which were mainly negative, were elicited at the pulmonary conus. At *C* the extrasystoles were initiated on the right free wall at a place between the trabecular zone and the pulmonary conus. The corresponding complexes were negative in the upper tracing (between points *2* and *1*) and the middle tracing (between points *3* and *1*) and positive in the lowest tracing (between points *3* and *2*).

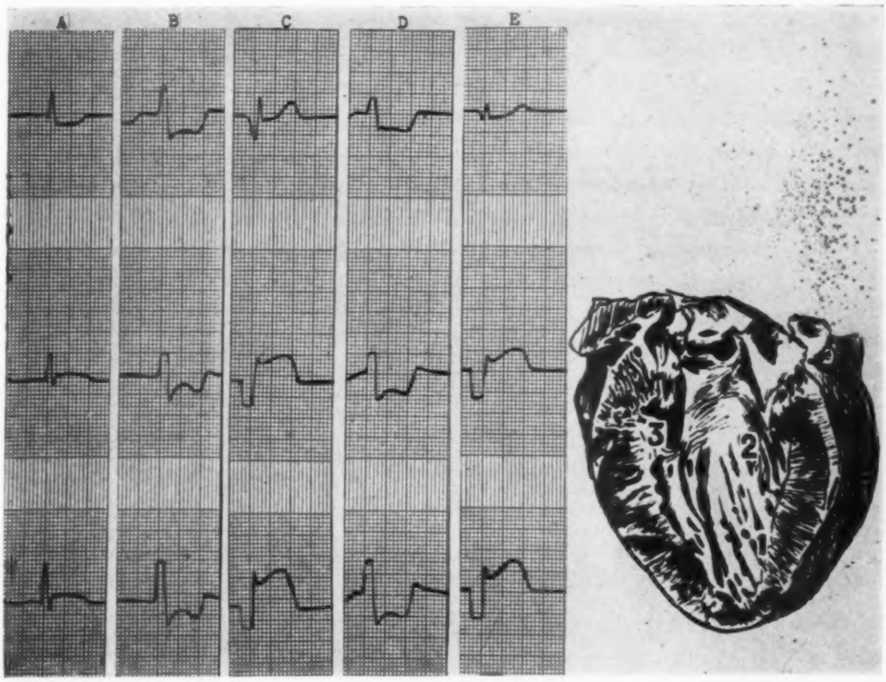


Fig. 2.—Distant bipolar leads on the left septal surface. *A*, Control tracings; *B*, extrasystoles elicited in the trabecular zone of the right ventricle; *C*, extrasystoles initiated at the base of the right ventricle; *D*, extrasystoles originated at the apex of the left ventricle; *E*, extrasystoles elicited at the base of the left ventricle.

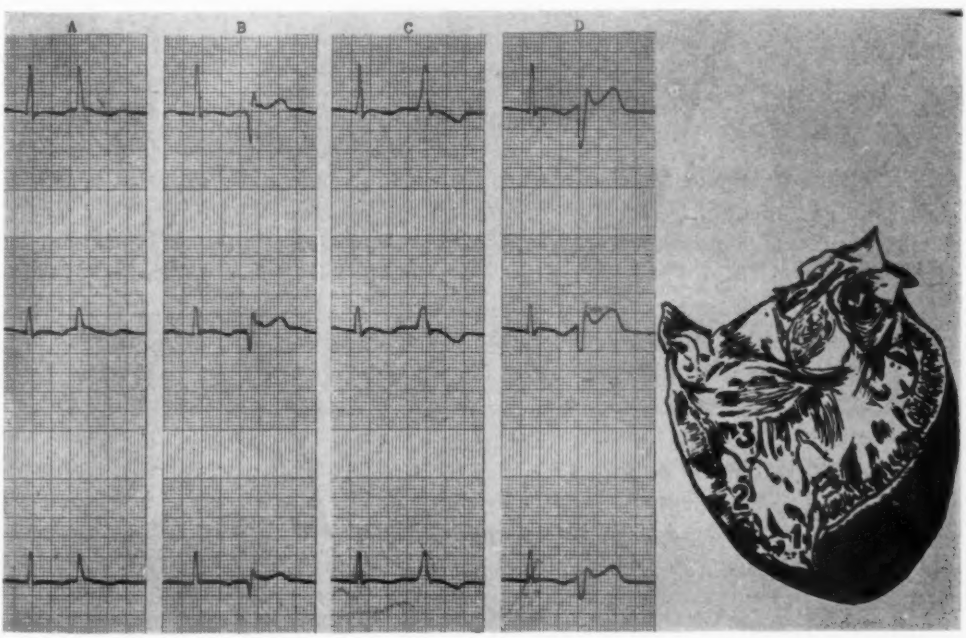


Fig. 3.—Different extrasystoles recorded with distant bipolar leads on the right septal surface (see text).

In Fig. 2,*B*, extrasystolic complexes are shown, elicited by the percussion of the apex of the right ventricle; they were essentially positive. At *C* negative areas predominated in the rapid ventricular complex of the extrasystoles obtained on the pulmonary conus. At *D* the extrasystoles were predominantly positive and were initiated at the left ventricular apex. At *E* the ectopic complexes were mainly negative and were obtained on the free wall of the left ventricle in its lateral and basal portions.

These experiments were repeated in various animals, and the results were constant. Always when the extrasystoles were elicited at the basal regions of the ventricles, the deflections as recorded on the septum were negative; if the extrasystoles were initiated at the apex of either ventricle, the rapid extrasystolic complexes were positive.

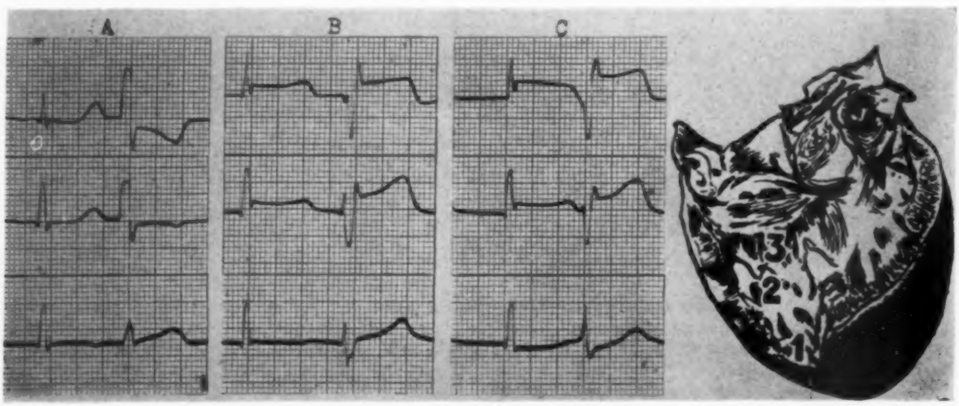


Fig. 4.—Extrasystoles recorded with distant bipolar leads on the right septal surface (see text).

The works of Barker and associates[11] indicated that the mean manifest axis of the QRS complexes of extrasystoles initiated at the apex was directed from below upward; when they originated at the base, the direction was reversed. For example, in one instance, $\hat{A}QRS$ of an extrasystole elicited at the apex of the left ventricle was found to be -120 degrees; when the extrasystole was initiated in the vicinity of the right ventricular apex, the vector $\hat{A}QRS$ was located at -60 degrees; in another case, $\hat{A}QRS$ was at $+45$ degrees, and the extrasystole was elicited on the basal and lateral portion of the right ventricle; in other ectopic beats of the basal and lateral portion of the left ventricle, $\hat{A}QRS$ was $+135$ degrees.

These observations reinforce our point of view, that when the ventricular extrasystoles originate at the apex of either ventricle, they enter the septum from below upward, coinciding with the general direction of the activation of the whole heart and consequently determining the predominantly positive deflections on the tracings obtained with distant bipolar leads. If the extrasystoles are basal, the general direction of activation is opposite and the deflections are negative. If we accept the preceding criterion, the finding of essentially positive complexes on the septum with distant bipolar leads suggests that the general

direction of the septal activation is from below upward. Other observations to which we shall refer later regarding the time of arrival of the activation wave at different points of the septum further strengthen this point of view.

2. Unipolar and Proximal Bipolar Leads.—With both types of leads a rather exact idea of the time of arrival of the activation wave at different points of the interventricular septum is obtained. We shall analyze successively the spread of the impulse on the right septal surface, the left septal aspect, and the muscular fibers forming the septum.

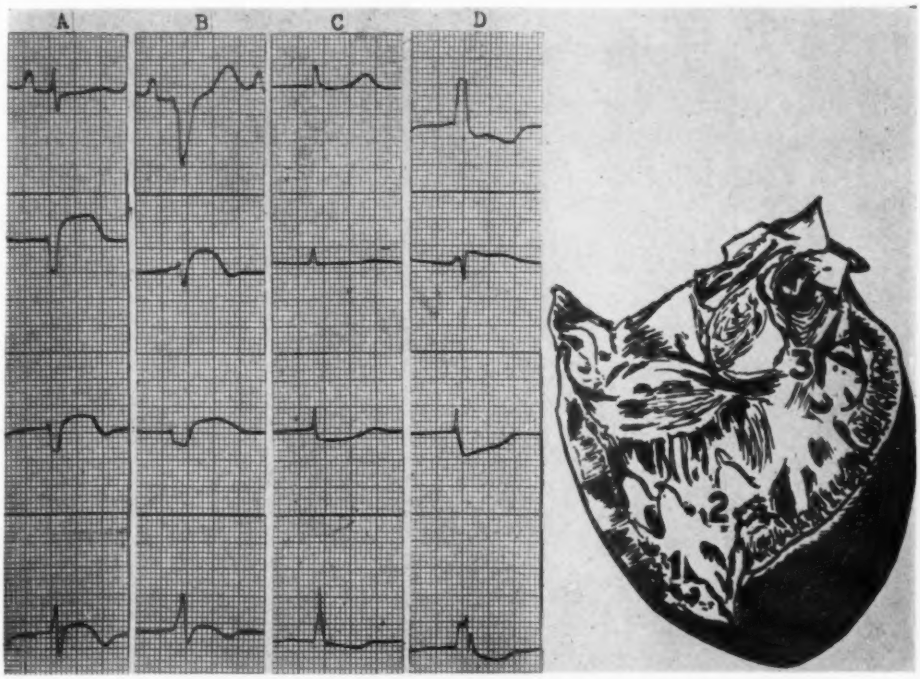


Fig. 5.—Unipolar and proximal bipolar leads on the right septal aspect. *A*, Lead II recorded simultaneously with unipolar leads at points *1*, *2*, and *3*;* *B*, the same leads as in *A* after a right bundle branch block; *C*, distant bipolar lead between points *2* and *1* (upper tracing) simultaneous with proximal bipolar leads of points *1*, *2*, and *3*; *D*, similar leads as in *C* after a right bundle branch block.

A. Right septal aspect: In the scheme of Fig. 5, the three points studied on the right septal aspect are shown. *A* corresponded to the unipolar tracings registered simultaneously with Lead II (upper tracing). Those corresponding to points *1* and *2* were of the rS type, and in both the intrinsic deflections were simultaneous. In this figure the tracing that corresponded to point *3* was of the RS type, and the intrinsic deflection was inscribed around 0.03 second later than the same line at points *1* and *2*. Based on the morphology of the tracing and on the delay of the intrinsic deflection, the statement can be made that point *3*, placed very close to the pulmonary valves, was activated later than the other two.

***In all the following figures, the tracings of point *3* are the lowest in each column; those of point *2* are located above and those of point *1* are still higher.**

The tracings obtained by the proximal bipolar leads on the same points are shown in *C* (three lower graphs). They were registered simultaneously with a distant bipolar lead taken from point *2* to point *1* (upper graph). The vertices of the largest deflections of the proximal bipolar leads occurred simultaneously at point *1* and point *2*; on the other hand, that of point *3* was inscribed 0.02 second later.

If the inferior vertex of the intrinsic deflection of each unipolar lead were referred to Lead II, it could be seen that in the unipolar tracing of points *1* and *2*, this vertex coincided with the beginning of the ascending branch of R in Lead II.

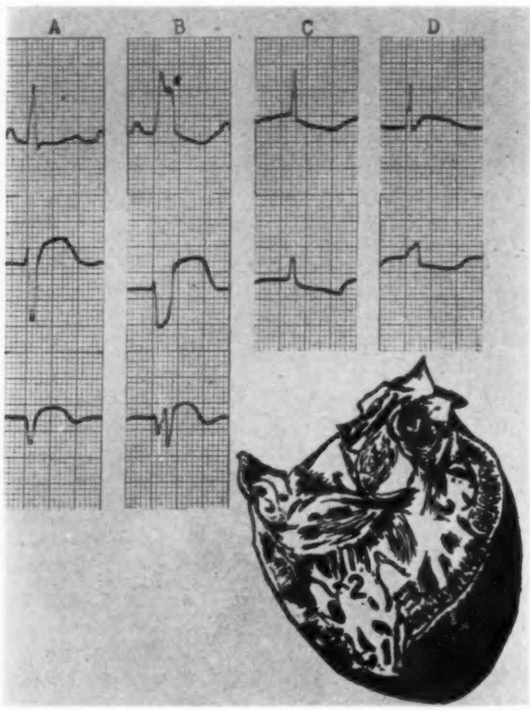


Fig. 6.—Unipolar and proximal bipolar leads from the right septal surface. *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1* and *2*. *B*, The same leads as in *A* with a left bundle branch block; *C* and *D*, proximal bipolar leads of points *1* and *2*: control tracings (*C*) and during a left bundle branch block (*D*).

In *B* the same leads are shown as in *A*, obtained after a right bundle branch block was elicited. In the unipolar lead of point *1*, the initial R was enlarged considerably, and there was a tendency for recording two positivities. The S wave diminished considerably in voltage and in duration. These changes were similar to those described on the unipolar epicardial tracings of the free wall of the right ventricle of the dog's heart after the right branch was cut. In the unipolar lead of point *2*, the initial R was identical to that which existed before the block; on the other hand, the S had increased in voltage and duration. These changes were similar to those described in some portions of the left ventricle

of the dog's heart after the right bundle branch was cut and suggested that point *2* does not depend for its activation on the right branch in spite of its localization on the right septal surface. Later on, we shall discuss this phenomenon and its possible explanation.

After the block, the unipolar tracings of point *3* showed an increased voltage of R and a smaller S as compared with the control tracings. The sequence of the inscription times of the intrinsic deflections in the unipolar leads existing before the block had disappeared. Now the deflection of point *2* was recorded around 0.02 second before the deflection of point *1* and 0.06 second before that of point *3*. In *D* the bipolar leads (lower tracing) of the same points are shown after the appearance of the right bundle branch block. They were simultaneous with the distant bipolar lead from point *2* to point *1* (upper tracing). The vertex of the proximal bipolar lead at point *2* was inscribed around 0.025 or 0.03 second before the same vertex at point *1* and approximately 0.045 second before the corresponding one at point *3*. In spite of the fact that the bipolar tracing at this point showed extrinsic phenomena, the line corresponding to the activation of the interelectrodal zone was quite well defined. The tracings obtained with distant bipolar leads (upper tracing at *D*) were similar to those obtained in cases of bundle branch block when they were recorded from one septal surface to the other at points lying at the same level[16] (in man as well in animals). In this case, however, they were taken from the right septal surface but at different levels.

In another experiment, two points of the right septal surface were explored. One of them (Fig. 6, point *2*) behaved as though it belonged to the left ventricle. Both points were activated almost simultaneously. When a left block was elicited, point *2* was activated, according to the proximal bipolar leads, around 0.03 second later than point *1*. By the unipolar tracings we recognized through which branch the activation reached the explored sites. After the left bundle branch was blocked, the voltage of R in the unipolar lead from point *1* was diminished, while the duration of S was increased. The inferior vertex of the intrinsic deflection at the same point corresponded, before and after the block, to some part of the ascending branch of R in Lead II (upper tracing). Before the block, the unipolar tracing of point *2* was of the QS type; now, however, it changed considerably and became rsRS. The vertex of the second intrinsic deflection corresponded to the end of the plateau of R in Lead II. This region was activated very late in the cardiac cycle.

In the diagram of Fig. 7, three points are shown that were explored on the right septal aspect. The first was close to the base of the papillary muscle, the second corresponded to the middle region of the septum, and the third was close to the tricuspid valves. The bipolar leads of the control corresponding to each of these points are shown in *A*. With the upper vertex of the major deflection as a reference, it appeared that point *1* was activated very slightly before point *2* and 0.025 second before point *3*. In several experiments it was observed that the muscular portion in contact with the base of the anterior papillary muscle was activated before any other point of the right septal aspect. After the right branch was cut, the activation of these three points occurred at practically the same instant (Fig. 7,*B*). This can be explained by the fact

that, after block, activation of these three points depended on spread of the activation wave from the normally activated left ventricle, which was near these three points.

The small difference in time of activation of points *1* and *2* before the block suggests that the pathway of the activation wave was across the Purkinje fibers, while the relatively later activation of point *3* with reference to point *2* (0.025 second) would indicate that the Purkinje fibers in this region were sparse or absent. This assumption is similar to that of Lewis mentioned in the introduction to this article.

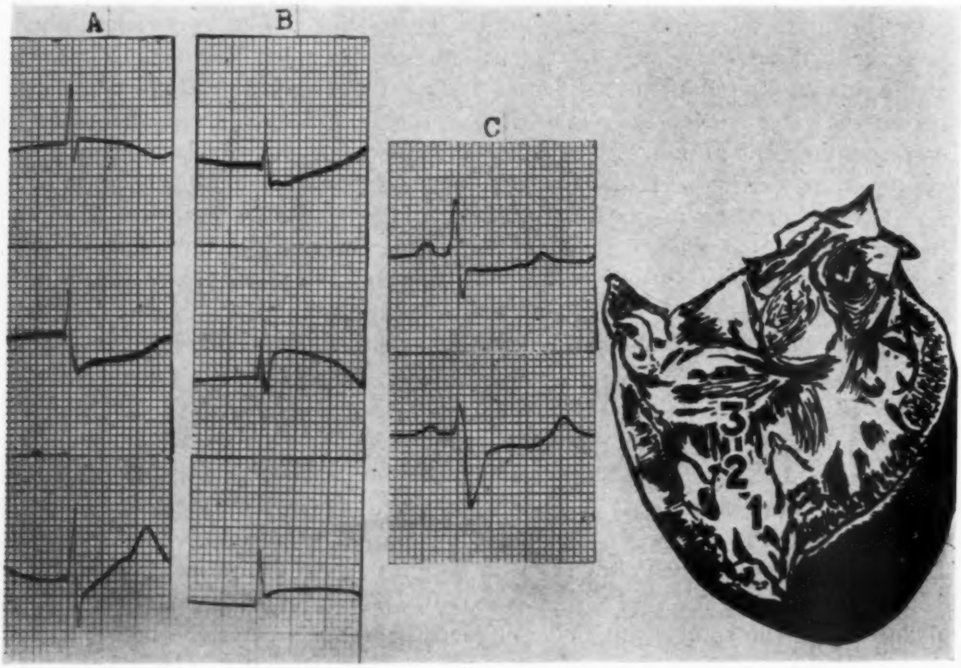


Fig. 7.—Proximal bipolar leads on the right septal surface. *A*, Control tracings of points *1*, *2*, and *3*; *B*, the same leads as in *A* after a right bundle branch block; *C*, Lead II of the control, upper tracing, and during a right bundle branch block, lower tracing.

In another experiment two points on the right septal aspect were explored (Fig. 8). One of these points was in a zone below the triscuspid valves; the other was situated at the base of the papillary muscle. The proximal bipolar leads (Fig. 8, *C*) showed that point *2* was activated around 0.005 second before point *1*. In the control unipolar tracings (Fig. 8, *A*) the intrinsic deflection of point *2* was recorded slightly before the same deflection of point *1*, and the inferior vertex of the first corresponded to the initial portion of the ascending branch of R in Lead II. Fig. 8, *B*, shows unipolar tracings with a certain degree of incomplete block of the left branch, recorded simultaneously with Lead I (upper tracing), since this lead demonstrated the incomplete block most clearly. Also, here the inferior vertex of the intrinsic deflection at point *2* was recorded before the corresponding vertex at point *1* and before the beginning of QRS in

Lead I. In this experiment it is apparent that both these points were activated by the right bundle branch, since their activity was not retarded by the incomplete block of the left branch.

In another experiment, three points were explored on the right septal aspect (Fig. 9), point *1* near the apex of the right ventricle, point *2* next to the anterior papillary muscle, and point *3* close to the tricuspid valve. By means of proximal bipolar leads (Fig. 9, *D*) it was noted that point *1* was activated 0.005 to 0.01 second before point *2*. The unipolar leads (Fig. 9, *A*) showed that points *1* and *2* pertained to the left ventricle, since the incomplete block (Fig. 9, *B*) and the complete block (Fig. 9, *C*) of the right branch resulted in considerable enlargement of the area of the negative complexes. The unipolar lead of

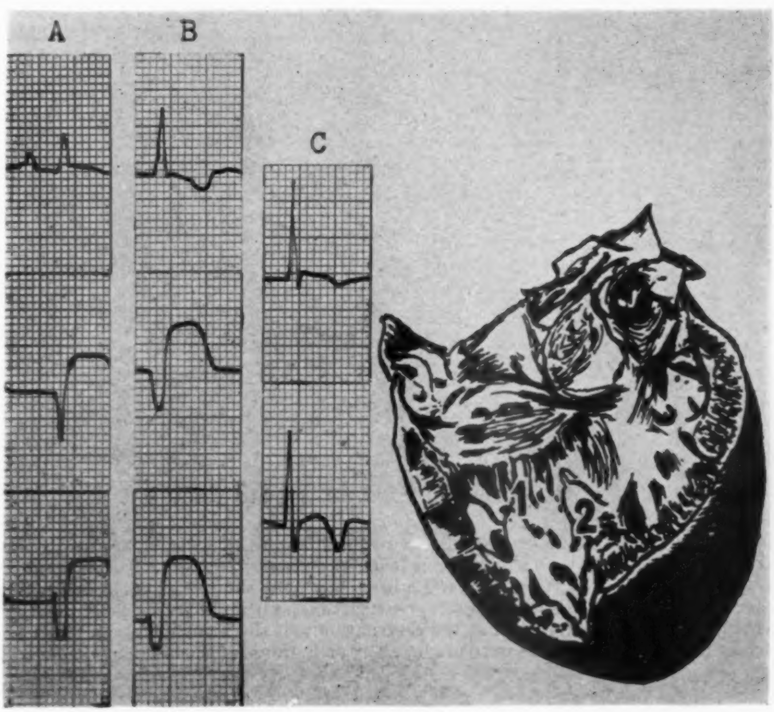


Fig. 8.—Unipolar and proximal bipolar leads from the right septal surface. *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1* and *2*. *B*, The same leads as in *A* during a left bundle branch block; *C*, control tracings, proximal bipolar leads points *1* and *2*.

point *3* was changed little with the incomplete block of the right branch, but when the block was complete, a late positive deflection appeared and the intrinsic deflection was considerably delayed. If these changes were not produced by an increase of the injury caused by the electrode's pressure, the explanation of this phenomenon is not altogether clear, but it is possible that the fibers supplying this particular area escaped injury during incomplete block and that their function was abolished only when the block became complete.

In Fig. 10, three points of the right septal surface are shown which behaved as though they belonged to the left ventricle. In fact, after right branch block

was elicited, the negative deflection of the unipolar tracings was enlarged and the intrinsic deflection was not retarded, nor were its relations to Lead II affected (Fig. 10, *A* and *B*). The bipolar leads before and after the right block showed no change in sequence or morphology. From these facts it was inferred that the three points were practically simultaneously activated.

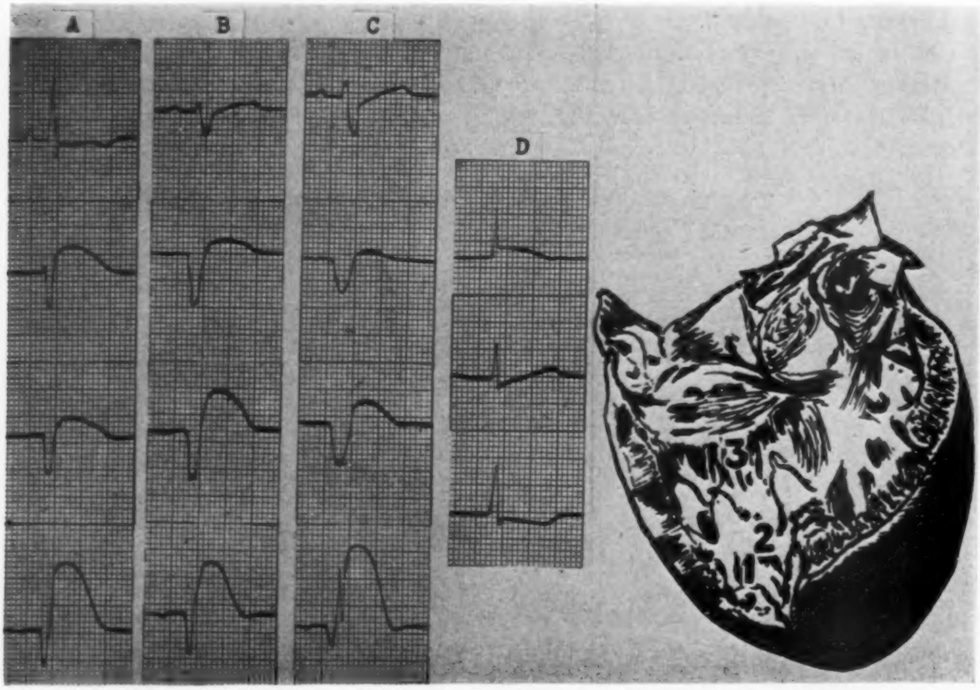


Fig. 9.—Right septal tracings: unipolar and proximal bipolar leads. *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3*. *B*, The same leads as in *A* during an incomplete block of the right bundle branch; *C*, the same leads as in *A* and *B* with a more complete block of the right bundle branch; *D*, proximal bipolar leads of points *1* and *2* during the control conditions. There is the possibility that the retardation and the morphology on point *3*, with a more complete right bundle branch block, were produced by an increase of the lesion at the moment of tapping the branch.

In Fig. 11, three points of the right septal surface are shown. The control bipolar leads (Fig. 11, *D*) showed that point *1*, the most proximal to the anterior papillary muscle, was activated before the other two and was the only region whose activation depended on the right branch, since with the complete block of the left branch (Fig. 11, *B*) the intrinsic deflection of the unipolar lead was not retarded. Points *2* and *3*, in spite of their location on the right septal surface, behaved as a left ventricular muscle. With the left branch blocked, a pronounced positive deflection appeared on the corresponding unipolar tracing, and the intrinsic deflection was considerably delayed (Fig. 11, *B*; the two lower tracings). The inferior vertex of the intrinsic deflection of the unipolar tracing of point *3*, with a complete block, was synchronous with the commencement of the descending branch of R in Lead II. This suggested that this point was activated late in the cardiac cycle.

When there was an incomplete block of the left branch, the only point that was delayed in its activation was point *3*, which was high in the septum. Here again, a fact similar to that of the corresponding experiment in Fig. 9 was repeated.

In *E* proximal bipolar leads after incomplete block of the left branch are shown. Point *2* was delayed 0.01 second and point *3* 0.02 second in relation to point *1*.

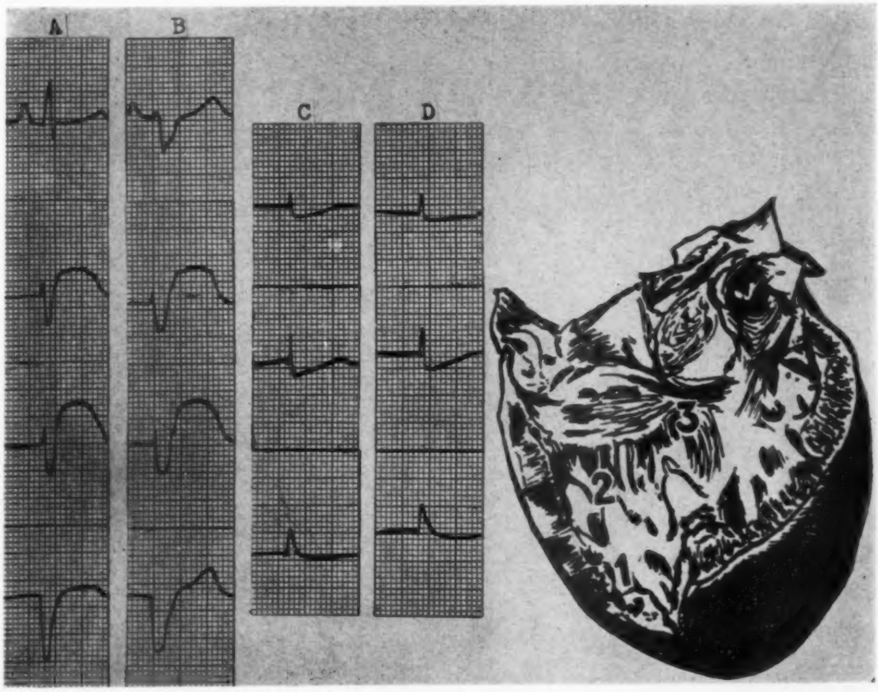


Fig. 10.—Unipolar and proximal bipolar leads of three regions on the right septal surface, activated through the left bundle branch. *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3*. *B*, The same leads as in *A* after a right bundle branch block was elicited. After the block, the intrinsic deflection of the unipolar tracings was not delayed although the S wave was broadened. *C*, Control tracings. Proximal bipolar leads of points *1*, *2*, and *3*; *D*, same leads as in *C* after a right bundle branch block.

The case that corresponds to Fig. 12 is interesting because in it three points are studied whose activation depended on the left branch. Two were located on the right septal surface and one on the left septal surface. With a right block, the unipolar tracings broadened in their negative phase and the intrinsic deflection was not delayed. By means of the bipolar leads, it may be shown that point *1*, near the apex of the right ventricle, was activated about 0.005 second before point *2*, placed on the left septal aspect near the base, and about 0.01 second before point *3*, located on the right septal aspect near the pulmonary valves. It appeared that the region of the septum close to the apex of the right ventricle, but belonging to the left ventricle, was activated before the basal portions on the left septal surface. On the other hand, in the experiment of Fig. 13, the activation of the apex of the right ventricle started 0.02 second later

than the corresponding activation at two points lying at the base of the left septal aspect. We believe that in this case the point depended for its activation on the right bundle branch. It is interesting to note the relations that existed between the inferior vertex of the intrinsic deflection at points *2* and *3* and the vertex of the major positivity at the bipolar lead of point *3*.

B. Left septal aspect: In other experiments we succeeded in locating three points on the left septal aspect (Fig. 14, *A*, *B*, and *C*) and also three on the right septal aspect (Fig. 14, *D*, *E*, and *F*). The first region activated on the left aspect was point *2* located in the center of the left surface of the septum at a place approximately halfway between the apex and the base. The inferior vertex of the intrinsic deflection at this point (*A*, third tracing) corresponded to the beginning of QRS in Lead II (*A*, upper tracing) and was earlier than the vertices corresponding to the other two points.

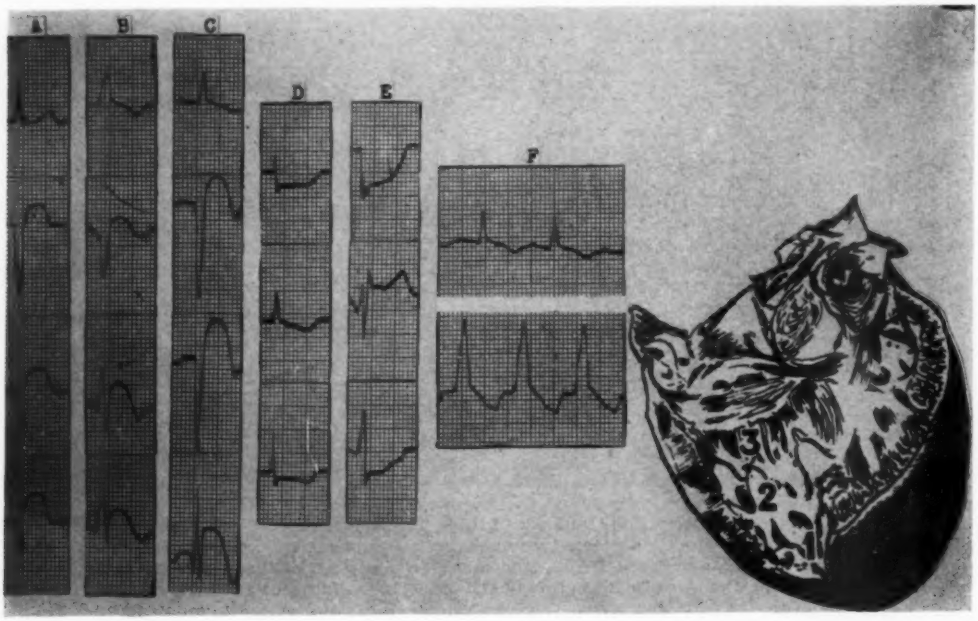


Fig. 11.—Unipolar and proximal bipolar leads from three regions of the right septal aspect. One region is activated through the right bundle branch (point *1*), the other two by the left bundle branch (points *2* and *3*). *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads from points *1*, *2*, and *3*. *B*, The same leads as in *A* during a complete block of the left bundle branch; *C*, the same leads as in *A* and *B* during an incomplete block of the left branch; *D*, Control tracings with proximal bipolar leads of points *1*, *2*, and *3*; *E*, the same leads as in *D* after an incomplete left branch block; *F*, the upper line shows the control of Lead II. The lower tracing corresponds also to Lead II after a complete left bundle branch block. There is a lengthened P-R interval during the left branch block.

The activation of the three left points was through the left bundle branch, since after a left branch block was established, the unipolar leads changed to QRS type, and the intrinsic deflection was delayed considerably. With a right block, the negative area increased in the same tracings, but the intrinsic deflection was not delayed. Point *3* of the left aspect was activated late in the cardiac cycle in the presence of left branch block, and the inferior vertex of the cor-

responding intrinsic deflection was synchronous with the beginning of the descending branch of R in Lead II (Fig. 14, *B*).

On the right, points *2* and *3* depended electrically on the left branch, while point *1* depended on the right branch. The changes produced on the unipolar leads after incomplete block of the left branch (*E*) and after right block (*F*) confirmed the foregoing.

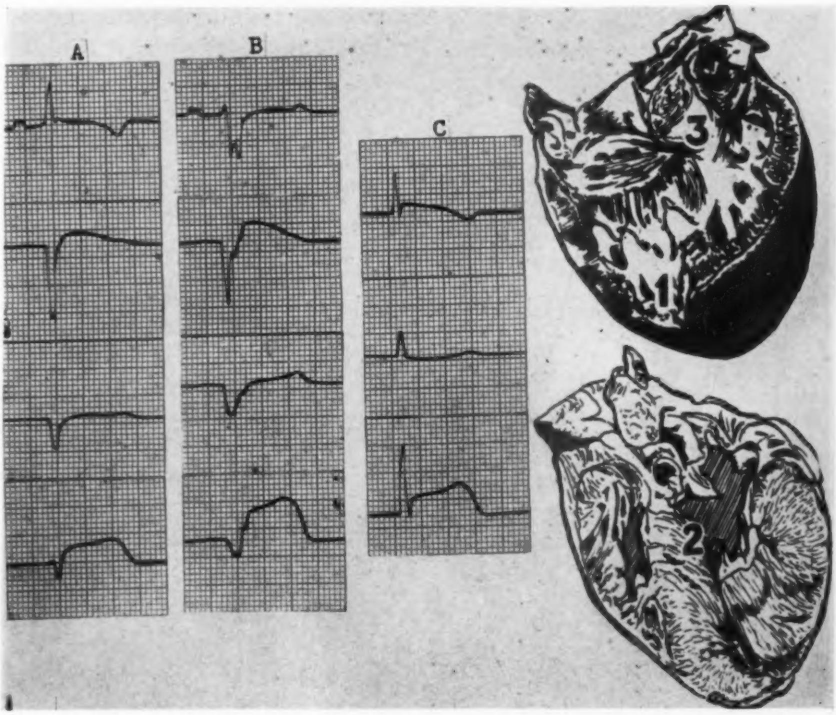


Fig. 12.—Unipolar and proximal bipolar leads of three points whose activation depends on the left branch of the bundle of His; points *1* and *3* are located on the right septal surface and point *2* on the left septal surface. *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3*. *B*, The same leads as in *A* after a right branch block was elicited; *C*, proximal bipolar leads of points *1*, *2*, and *3* under control conditions.

It is important to observe that point *2* on the left and point *2* on the right were activated at almost exactly the same moment (less than 0.005 second difference) whether there was (1) no block, (2) right block, or (3) left block. In other words, the passage of the impulse through the septal mass was rapid and of essentially the same duration whether it was traveling from left to right or vice versa. This strongly implies that the increased duration of QRS in bundle branch block is due, not to a delay in transmission of the impulse through the muscle forming the mass of the septum, but rather to an increase in the time required for the impulse to travel across from the intact to the affected side of the septum.

In the experiment corresponding to Fig. 15, two points on the right septal aspect and one on the left were studied. The activation of the two right points

depended on the right branch, as was shown by the changes produced in the unipolar leads after the right branch was blocked. On the other hand, the activation of the left point was through the left branch.

The unipolar and bipolar leads showed that point *2* was first activated synchronously with the first portion of the ascending branch of R in Lead II. Point *1* was activated 0.01 second later, at approximately the same time as the vertex of R_2 was recorded. Point *3* was activated 0.02 second later than point *2*, when the vertex of S_2 was inscribed. The foregoing results illustrate the relations existing between the activations of the left and right septal aspects. Point *3* with a right branch block was activated very late in the cardiac cycle when the notch of S in Lead II was inscribed.

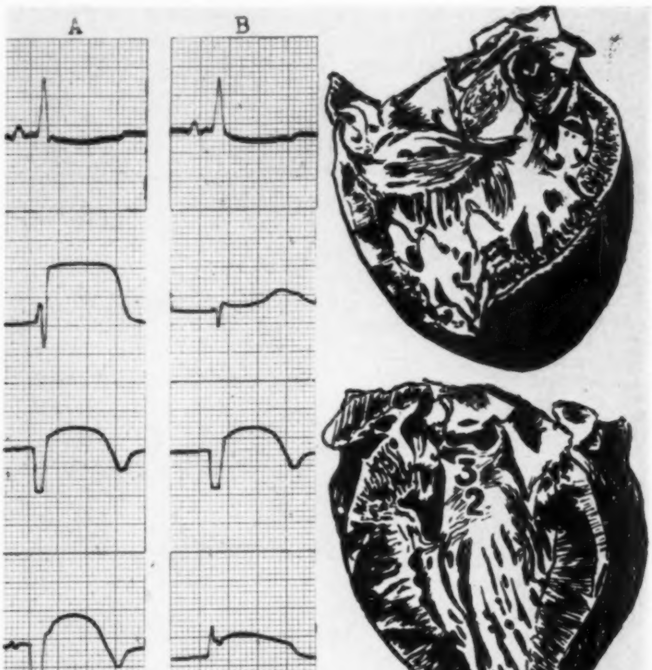


Fig. 13.—Unipolar and proximal bipolar leads from the right and left septal surfaces, showing the relation existing between the arrival of the activation wave at the apex of the right septal aspect (point *1*) and at the base of the left septal aspect (points *2* and *3*). *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3*. *B*, Lead II was recorded simultaneously with the bipolar lead of point *1* (second tracing), the unipolar lead of point *2* (third tracing), and the bipolar lead of point *3* (fourth tracing). Observe that the sequence between the vertex of the major deflections on the bipolar leads coincides with that shown by the inferior vertex of the intrinsic deflections on the unipolar leads.

In the experiments corresponding to Fig. 16, three points on the left septal aspect were studied whose activation, according to the intrinsic deflection of the unipolar leads (Fig. 16, *B*), was practically synchronous with the beginning of R in Lead II (Fig. 16, *A*). When a left block was established (*C* and *D*), the complexes changed from a QS type to qRS, and the activation of the three points continued being practically simultaneous, but now synchronous with the second

vertex of R in Lead II. These three points were activated, then, very late in the cardiac cycle. If, on the other hand, the block was on the right side, they were activated at the beginning of the ventricular complex (Fig. 16, *E*).

In the experiment corresponding to Fig. 17, three points on the left septal surface were studied, and both on the normal tracings (*A*) and when a block existed in the right branch (*B*), the inferior vertex of the intrinsic deflection of point *2* was inscribed slightly less than 0.005 second before the corresponding one on point *1*, and 0.005 or 0.01 second before that at point *3*. Also, it was synchronous with the commencement of QRS in Lead II. When there was a left block, the three points were retarded in their activity; point *1* continued to be before *3*, but it was not possible to determine their relations with point *2* precisely, apparently because of injury produced by the electrode.

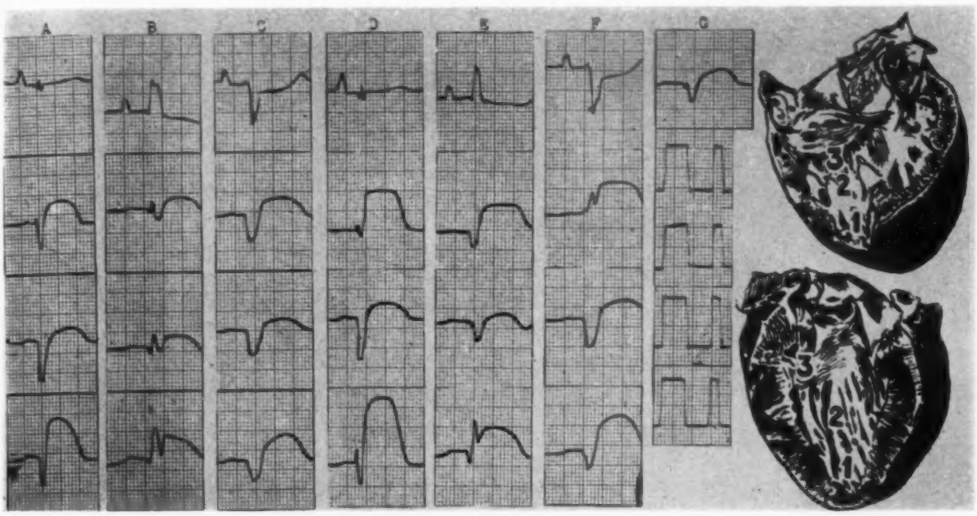


Fig. 14.—Unipolar leads from the right septal aspect (upper diagram) and left septal aspect (lower diagram). *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of the points *1*, *2*, and *3* on the left septal surface. *B*, The same leads as in *A* during a complete left bundle branch block; *C*, same leads as in *A* and *B* during a right bundle branch block. *D*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3* on the right septal surface. *E*, The same leads as in *D* during an incomplete block of the left branch; *F*, the same leads as in *D* and *E* with complete block of the right branch; *G*, upper tracing: unipolar lead of point *2* on the right septal surface with a greater degree of block than the corresponding tracing in *E*. The succeeding tracings on the same column show the control of standardization on the four channels to control their asynchronism.

In the experiment of Fig. 18, three points on the left surface were studied. The bipolar leads showed the greatest differences in the arrival of the activation wave at the different points. Point *2*, lying between the base and the apex, was activated 0.015 or 0.02 second before points *1* and *3*. The unipolar leads checked by tracings from each of the two contacts of the electrode were in accord with the findings.

In Fig. 19 are shown three points studied in another experiment. Two were located on the left septal surface and one (point *2*) on the anterior papillary muscle outside of the septum, but in the left cavity. The unipolar and bipolar

leads showed that the first to be activated was that one located below the aortic valves. Its activation, nevertheless, although early, was less than the points located on the medial part of the septum between the apex and the base, since the inferior vertex of the intrinsic deflection of point *3* corresponded to the vertex of Q in Lead II.

The other two points were activated at the same time and about 0.005 second after point *3*. This activation was synchronous with the first portion of the ascending branch of R_2.

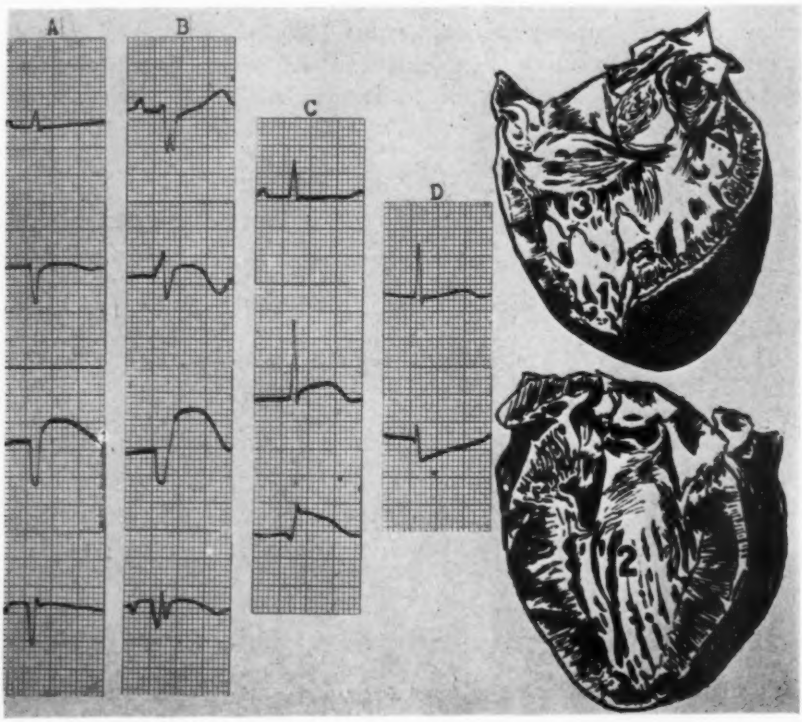


Fig. 15.—Unipolar and proximal bipolar leads from the right and left septal aspects. Points *1* and *3* correspond to the right septal surface and point *2* to the left septal surface. *A*, Control tracing. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3*. *B*, The same leads as in *A* after a right bundle branch block. Observe the changes of the right septal points, indicating that their activation arrives through the right bundle branch, in contrast to the left septal point corresponding to the left bundle branch. *C*, Control tracings. Lead II was recorded simultaneously with proximal bipolar leads of points *2* and *3*. *D*, Control tracings from points *1* and *2* obtained with proximal bipolar leads.

When there was an incomplete block of the left branch, the control complexes of the QS type turned to rS (*B*); the point most in advance continued to be *3*, and its activation corresponded to the medial part of the ascending branch of R in Lead II. When the left block was complete (*C*), the three points were activated simultaneously and were synchronous with the vertex of R_2. When there was a right block (*D*), the initial R of the unipolar leads disappeared and through the intrinsic deflection of these, it can be inferred that point *3* continued to be the most advanced in activation. The proximal bipolar leads of points *1*

and *3* after a right block (*F*) were satisfactory and showed the same sequence that was shown by the unipolar leads. The bipolar lead of point *2* was not useful.

The experiment of Fig. 20 is interesting because it shows the variations of the unipolar tracings of three points on the left septal surface with varying degrees of block of the left branch. On point *3* of the control (*A*), there existed an initial positivity that did not disappear when there was a right block (*E*). On the other hand, with different degrees of left block, this positivity increased in voltage and retarded according to the magnitude of the conduction overturn. Also bipolar leads are shown that were carried in the usual manner.

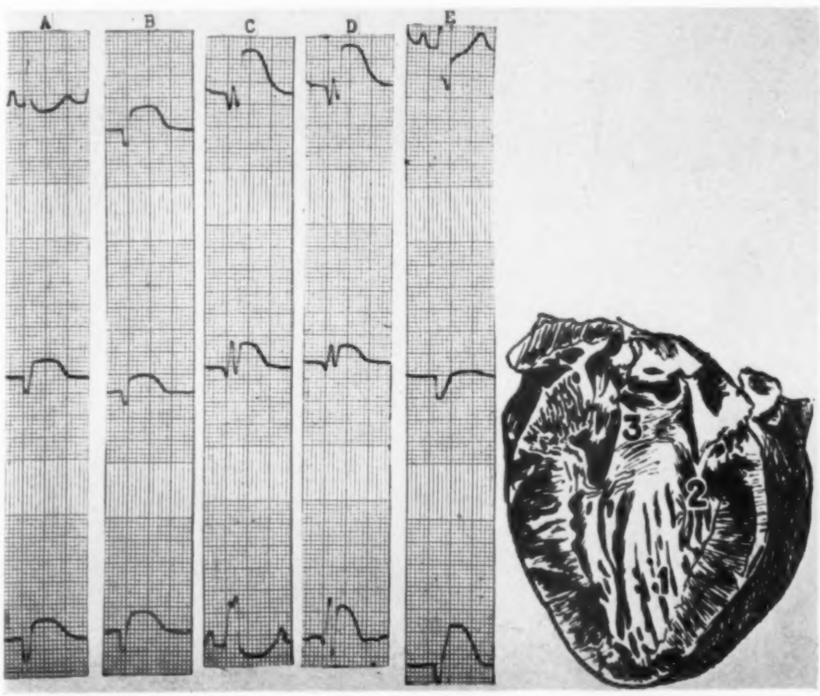


Fig. 16.—Unipolar leads from the left septal surface. *A*, Control tracings. Lead II was recorded simultaneously with unipolar leads of points *2* and *3*. *B*, Control tracings; unipolar leads of points *1*, *2*, and *3*. It can be observed that the activation on the three points is practically simultaneous and synchronous with the beginning of R on Lead II. *C*, Unipolar tracing of points *1* and *2* recorded simultaneously with Lead II (third tracing) after left bundle branch block was elicited. *D*, Unipolar leads of points *1*, *2*, and *3* with left bundle branch block. With this block, the activation of the three points is delayed and becomes synchronous with the second vertex of R on Lead II. *E*, Lead II was recorded simultaneously with the unipolar leads of points *1* and *2* during a right bundle branch block. Observe that both points continue to be activated at the onset of the ventricular complex.

The case corresponding to Fig. 21 is interesting because it shows a point (Fig. 21, point *1*) on the left septal surface whose activation depended on the right branch. In the control (*A*, tracing *2*) the unipolar lead was of the rS type, and the vertex of the intrinsic deflection corresponded to the inferior one-third of R in Lead II, approximately 0.01 to 0.015 second after the beginning of the ventricular complex. On the other hand, when there was a right block, the tracing

turned to rSR, and the inferior vertex of the second intrinsic deflection was inscribed about 0.07 second after the beginning of QRS. The other two points depended electrically on the left branch, and the corresponding unipolar leads were carried in the usual way in the two types of blocks. The proximal bipolar lead of point *1* also showed how the vertex of the greater deflection was not modified in its relations with the onset of QRS in Lead II when a block of the left branch appeared (*I*, second tracing). On the other hand, it was considerably retarded with a right block (*K*, second tracing). The proximal bipolar lead was taken only in the presence of an incomplete block of the left branch.

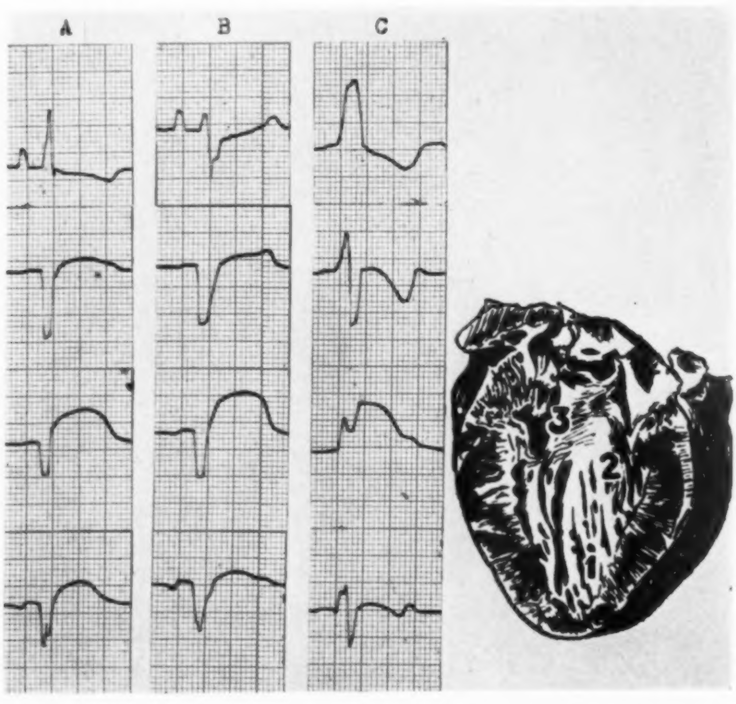


Fig. 17.—Unipolar leads on the left septal aspect. *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3*. *B*, The same leads as in *A* during a right bundle branch block; *C*, the same leads as in *A* and *B* after complete block of the left bundle branch was elicited. It was not possible to determine the relations of the unipolar tracing corresponding to point *2* on this column due to the magnitude of the lesion that had set in.

The proximal bipolar leads of points *2*, *3*, and *4* were transformed considerably with a right block, thus making their interpretation difficult.

This experiment was the only one in which a point of the left septal surface behaved as though it belonged to the right ventricle.

C. Activation on the interior of the septum: In some experiments, the lead points did not appear at any of the septal surfaces, permitting one to take tracings in the mass of the septum. By the tracings obtained, we supposed that the activation of the major part of the septum depended on the left branch and that the left ventricle approached considerably nearer to the right septal sur-

face. However, in an experiment (Fig. 22) a septal point high in the thickness of the interventricular septum and at approximately the same distance from both septal surfaces was explored. The rapid ventricular complex of the unipolar lead remained negative (complex QS) in the control and in the tracings corresponding to the branch blocks. The vertex of the intrinsic deflection was inscribed about 0.01 second after the beginning of QRS in Lead II. After branch block was elicited, appreciable retardations were not found in the inscription of this vertex, though there were small variations. In another similar case we found also that the unipolar lead of the control was not modified after branch block was elicited.

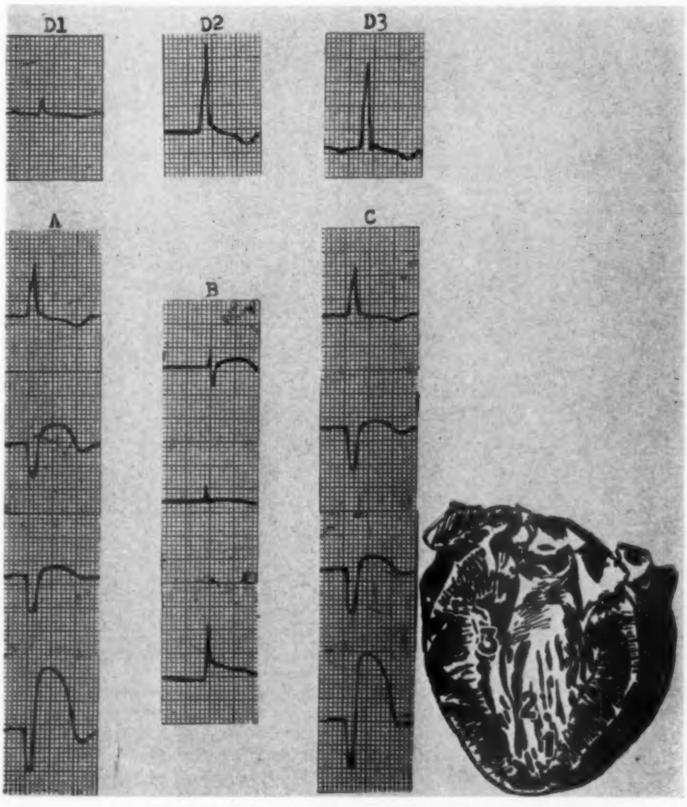


Fig. 18.—Standard leads; unipolar and proximal bipolar leads on the left septal surface. The upper series corresponds to the control tracings of the standard leads (I, II, and III). *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3*; they were taken with one of the contact leads of the proximal bipolar electrodes used in the experiment. The unipolar leads corresponding to the other contact are shown in the same order in *C*. They were recorded simultaneously with Lead II. *B*, Control tracings from points *1*, *2*, and *3* taken with proximal bipolar leads.

There is the possibility that high points existed on the septal mass whose activation did not depend on any of the branches, but on some accessory bundle as is described by Mahaim and Winston[12] (paraspecific bundle) in these places. Nevertheless, our experiments are few, and for the present we do not feel that we should draw any definite conclusions.

Differences Between the Right Intracavitary Potential and the Right Septal Surface Potential.—In the dog's heart, the normal intraventricular tracing was of the rS type (Fig. 23, *A*). It turned to RS type with initial slurring of R after a right branch block of the bundle of His (Fig. 23, *B*). These intracavitary morphologies can be registered on the right septal surface. But from the moment that we found different forms on this surface, it was easy to understand that notwithstanding the recording on the same level, the intracavitary tracings could be different from the septal tracing.

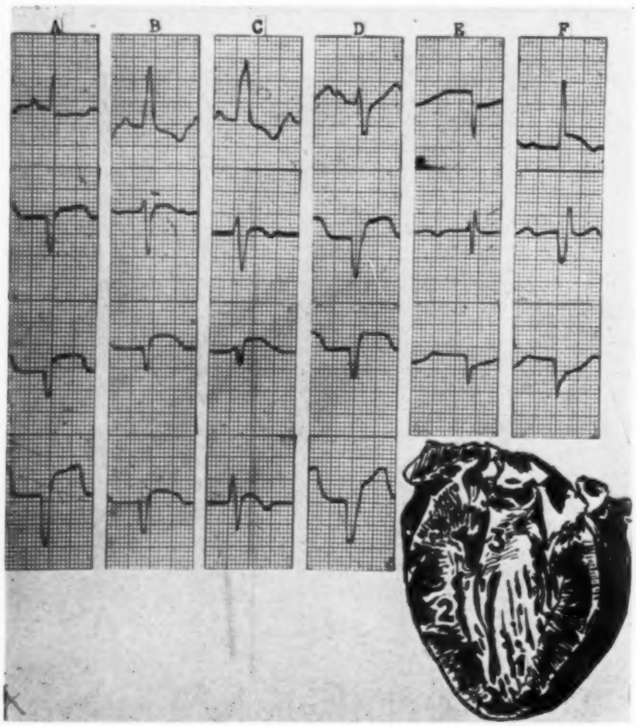


Fig. 19.—Unipolar and proximal bipolar leads from the left septal aspect (points *1* and *3*) and from the left papillary muscle (point *2*). *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3*. *B*, The same leads as in *A* during an incomplete left bundle branch block; *C*, the same leads as in *A* and *B* with a complete block of the left branch; *D*, similar leads as in *A*, *B*, and *C* during a block of the right branch; *E*, control tracings: proximal bipolar leads of points *1*, *2*, and *3*; *F*, the same leads as in *E* after a right bundle branch block.

Fig. 23 corresponds to an experiment in which a catheter was introduced into the right ventricular cavity whose zone of registration was located in front of the base of the right papillary muscle; with the septal electrode (already described) it was derived from the same level on the right septal surface. The unipolar leads of the control were very similar to each other (Fig. 23, *A*, inferior tracings), while those recorded after a right branch block were different (Fig. 23, *B*, inferior tracings). The intracavitary tracing became of the RS type, and on the septal surface the R wave was kept equal and the S wave was enlarged considerably, which suggested that the activation arrived at this point by the left branch.

In another experiment we obtained similar results with the following technique. A unipolar electrode was introduced across the septum and it was recorded, after a right branch block, in the mass of the septum, near the right septal surface (Fig. 24, *C*), on the endocardium of the septal surface (Fig. 24, *D*), and in the right ventricular cavity (Fig. 24, *E*). The intraventricular tracing showed two positivities that did not exist on those taken directly in the septum. These differences explained to us the large variety of morphologies found by Kossmann and collaborators[13] in studying the right intracavitary potential in the human heart in right branch block. It was understood that the records obtained could be different, depending on whether the end of the catheter touched the interventricular septum or remained free in the cavity.

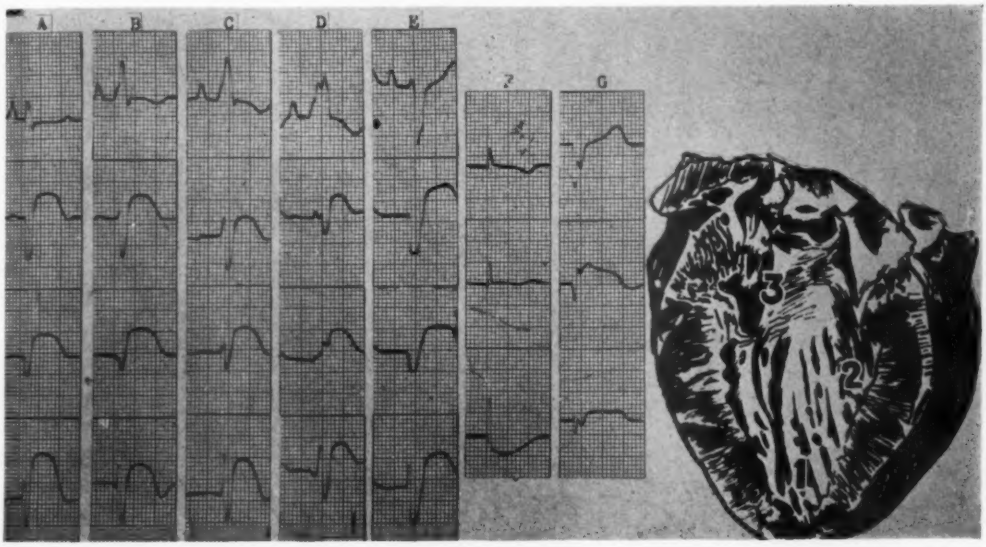


Fig. 20.—Unipolar and proximal bipolar leads of the left septal aspect. It is interesting to observe the changes in the unipolar tracings with variable degrees of left branch block. *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1*, *2*, and *3*. *B*, *C*, and *D*, The same leads as in *A* with variable degrees of left bundle branch block; *E*, the same leads as in the preceding columns with right branch block; *F*, control tracings: proximal bipolar leads of points *1*, *2*, and *3*. *G*, The same leads as in *F* after a right bundle branch block.

DISCUSSION

Our results indicate that the spread of the activation wave through the septum is different from that accepted by most authors. It has been stated that the activation wave invades the septum at a point immediately below the aortic valves and then spreads on the septal surfaces from above downward, penetrating the muscle from without inward. We shall consider the time of arrival of the activation wave (1) on the septal surfaces (left and right) and (2) within the interior of the septal muscle mass.

1. Activation of the Left Superficial Aspect of the Septum.—The activation is initiated probably in the region where the left branch of the bundle of His

begins to ramify. According to our results, the first regions to be activated are those lying midway between the anterior and posterior edges of the septum at the juncture of the lower two-thirds with the upper one-third of the septal surface. It is generally agreed that in this region lie the first ramifications of the left bundle branch. In general, these places are separated from the insertion of the aortic valves by a distance of approximately 2 or 3 cm. in the case of a medium-sized heart. In contrast to Lewis' observations, we noted only one instance in which the activation probably started immediately below the aortic cusps (Fig. 19).

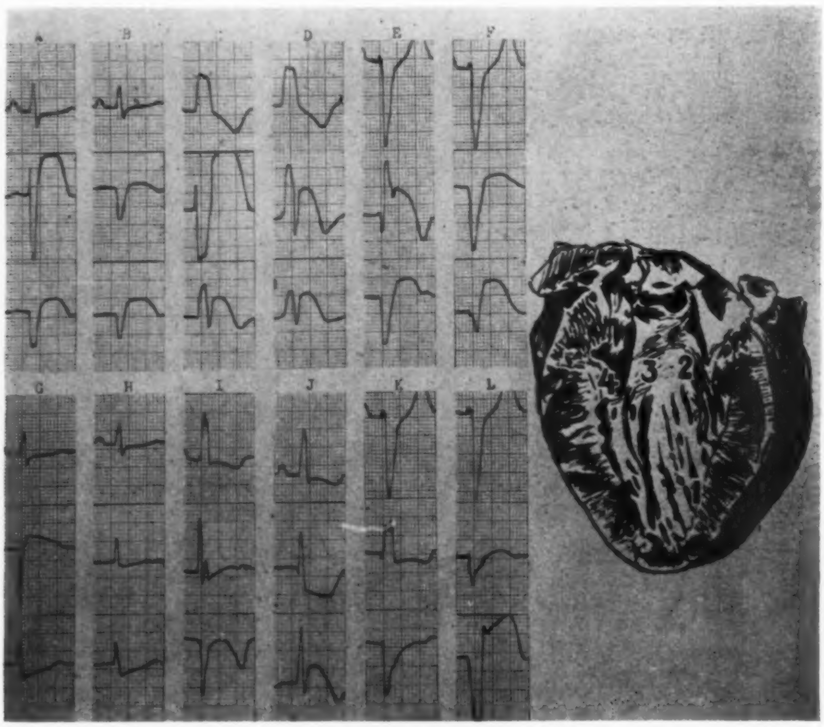


Fig. 21.—Unipolar and proximal bipolar leads on the left septal aspect, showing a region (*1*) located on the posterior part and near the apex probably activated through the right bundle branch. This region is shown in Fig. 29. *A*, *C*, and *E*, Lead II was recorded simultaneously with the unipolar leads of points *1* and *2*: *A*, control tracings, *C*, during the left bundle branch block, *E*, during the right bundle branch block. *B*, *D*, and *F*, Lead II was recorded simultaneously with the unipolar leads of points *3* and *4*: *B*, control tracings, *D*, during a left bundle branch block, *F*, during a right bundle branch block. *G*, *I*, and *K*, Lead II was recorded simultaneously with the proximal bipolar leads of points *1* and *2*: *G*, control tracings, *I*, during a left bundle branch block, *K*, during a right bundle branch block. *H*, *J*, and *L*, Lead II was recorded simultaneously with the proximal bipolar leads of points *3* and *4*: *H*, control tracings, *J*, during a left branch block, *L*, during a right branch block.

From the point first activated, the process of activation is propagated very rapidly along the whole septal aspect, following the distribution of the Purkinje fibers. About 0.01 second after the first appearance of the activation wave on the septum, its spread can be detected along the anterior and posterior edges of the septum, in the region of the apex and in the area immediately subjacent

to the aortic valves. According to our findings, the last region to be activated is a basal zone very close to the anterior edge of the septum (Fig. 18, point *3*).

When correlated with Lead II, those regions which show earliest activation are either synchronous with the beginning of QRS or may even appear 0.005 second before the beginning of this complex. The major part of the remaining regions is activated during the inscription of Q in Lead II, and the latest point, already mentioned, is synchronous with a portion of the ascending branch of R at a point near its apex.

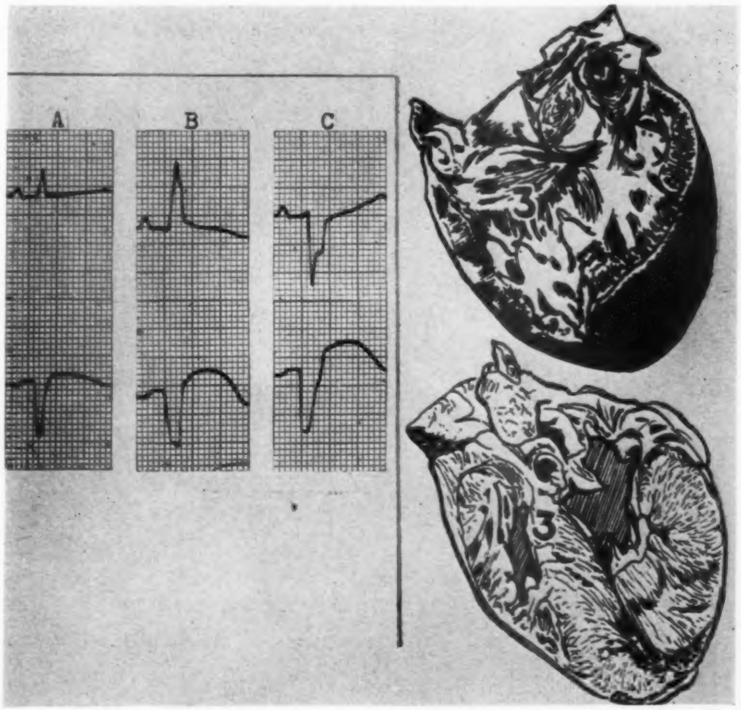


Fig. 22.—Unipolar leads within the interior mass of the interventricular septum. The point shown on the diagrams with the number *3* was located within the interior of the septum at an equal distance from both septal aspects and at a level corresponding to the insertion of the tricuspid valve. *A*, Control tracings. Lead II was recorded simultaneously with the unipolar lead of point *3*. *B*, The same leads as in *A* during a left bundle branch block; *C*, the same leads as in *A* and *B* during a right bundle branch block. Observe that there is no appreciable delay in the recording time of the intrinsic deflection of the unipolar leads with both types of blocks.

2. *Activation of the Right Septal Aspect.*—Activation begins in the region where, probably, the right branch of the bundle of His begins to ramify. The points first activated are those adjacent to the base of the anterior papillary muscle, and it is there also that the first subdivisions of the right branch have been described. These results are in accord with those described by Lewis and other authors.

The activation spreads from the base of the anterior papillary muscle to all the other regions of the right septal surface. It seems that the impulse spreads rapidly until it approaches the insertion of the pulmonary and tricuspid

valves. The apex of the right septal aspect is activated about 0.005 to 0.01 second later than the base of the right papillary muscle.

The impulse arrives later at the basal regions adjacent to the valvular insertions, about 0.025 to 0.03 second after the activation of the base of the anterior papillary muscle.

The arrival of the impulse at the region of earliest activity on the right septal aspect (the base of the anterior papillary muscle) proceeds synchronously with the beginning of the ascending portion of R in Lead II. It is preceded by the initiation of the activity on the left septal aspect by 0.01 second.

The activation of the basal regions was synchronous with the downstroke of the R or S wave of Lead II.

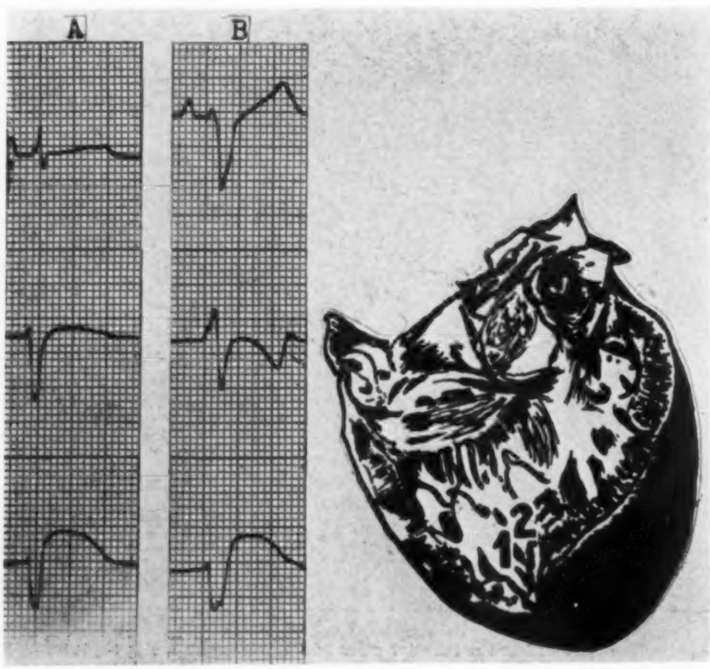


Fig. 23.—Unipolar leads from the right septal aspect and the right ventricular cavity. One electrode, introduced through a catheter into the cavity, was located near the right septal aspect between the apex of the right ventricle and the anterior papillary muscle (point *1*). With the septal electrode (described in the text) the lead was from a region of the septum located very close to the cavitary lead (point *2*). *A*, Control tracings. Lead II was recorded simultaneously with the unipolar leads of points *1* and *2*. *B*, The same leads as in *A* after a right bundle branch block.

3. Activation of the Muscle Mass of the Interventricular Septum.—It is well known, of course, that the interventricular septum is formed of muscular elements derived from both right and left ventricles, but the exact relative proportions deriving from each at a given level are difficult to determine. Anatomical study is complex, and histological differentiation is almost impossible. Nevertheless, as indicated by Scheme 2, in anatomical sections at different levels of the right aspect of the septum there are places where there are defects and in which the left ventricle actually forms the right aspect of the septum (Figs. 25,

26, 27). We believe that the regions of the septum which are formed only by the left ventricle are the closest to the levels of the trabecular zone; in this region, the right cavity practically disappears, while the left continues to the apex of the heart (Fig. 25). If these assumptions are correct, then it would be supposed a priori that the activation wave would appear first in those portions of the right aspect contributed by the left ventricle, the activation wave in this case having traversed the full thickness of the left ventricular mass. This, indeed, is what our experiments revealed, for the impulse always arrived at these points in less than 0.01 second after the earliest activation of the left septal aspect. This shows that the activation wave is propagated through the width of the septum at a faster rate than is usually stated.

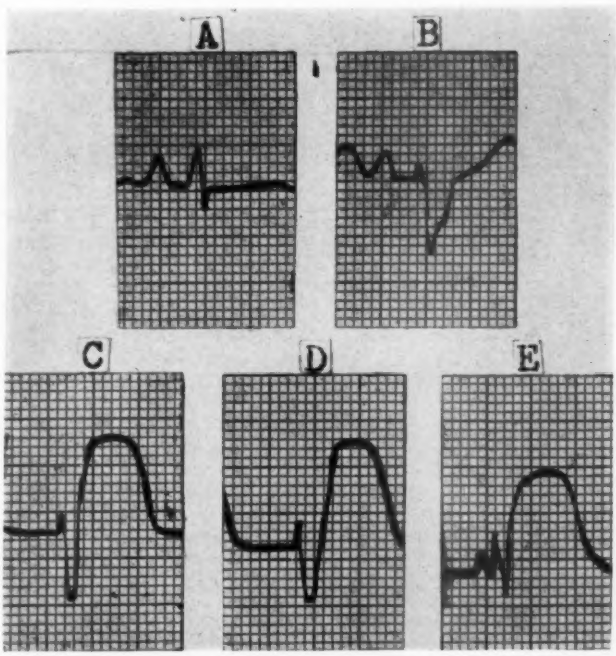
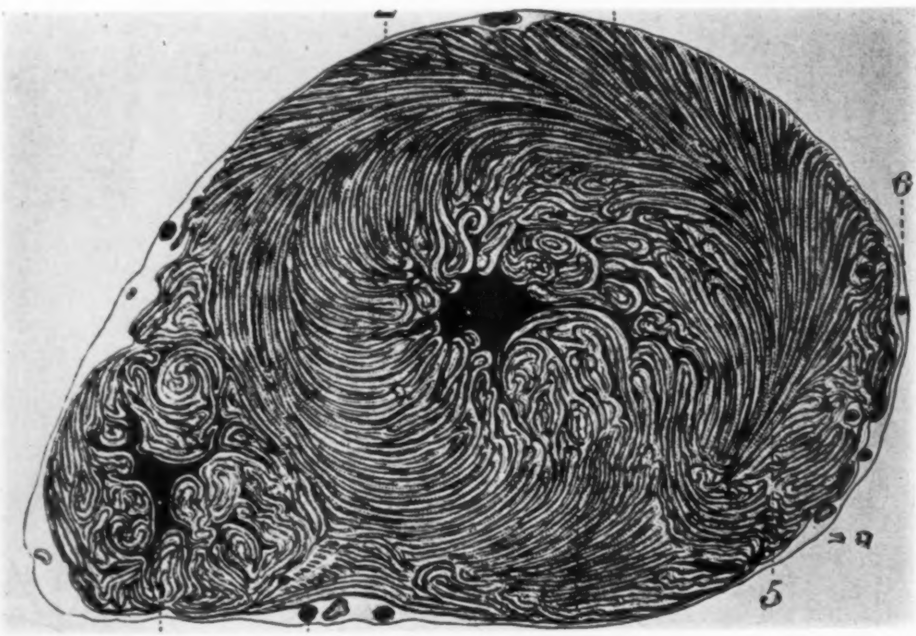


Fig. 24.—The upper tracings correspond to Lead II. *A*, Control tracing; *B*, during a right bundle branch block. The lower tracings correspond to right septal unipolar leads recorded during a right bundle branch block. *C*, The lead was from the interior mass of the septum near the right septal aspect. *D*, Tracings from the endocardium of the right septal aspect. *E*, Lead from the right ventricular cavity.

In an analogous manner, it appears that there are portions of the left septal aspect which are actually contributed by the right ventricle and therefore activated by way of the right branch. Anatomically, these areas are situated at sites high and posterior; at these levels, the left cavity ends, while the right continues toward the back (Fig. 28). In the present experiments, we did not attempt to explore these regions. Singularly enough, however, in one instance (Fig. 21) we encountered the electrical pattern that we would have expected had the activation wave spread via the right branch. Anatomically, this point was far removed from the locations (Fig. 29) where one would have expected to encounter right

ventricular tissue. We are unable to account for this discordance between electrical pattern recorded and the anatomical situation obtaining at this point.

When electrodes were introduced into the muscle mass of the lower portions of the septum, it was found that sectioning of either branch modified the pattern quickly and profoundly. On the other hand, unipolar tracings obtained from higher points within the septal muscle were not greatly modified by sectioning of the branches (Fig. 22). These sites correspond approximately to the place where Mahaim and Winston[12] described the paraspecific bundle, which originated directly from the bundle of His without having necessarily any connection with the branches. The activation wave may proceed through this bundle independently of activity in the usual branches. Actually, however, we have performed very few experiments dealing with this point, interpretation of the tracings has been difficult, and full clarification of the problem must therefore await further study.



Scheme 2.—Taken from Testut.[14]

4. General Process of the Activation of the Interventricular Septum.—The experimental evidence favors the view that the general direction of the activation process is from below upward. The tracings obtained by the use of bipolar leads with distant electrodes were in favor of this. The fact that the last points that were activated were those corresponding to the basal regions proximal to the tricuspid and pulmonary valves also strengthens this idea.

The former views suggest the discussion of other problems of electrocardiography, especially the interpretation of the normal Q wave, the QRS duration in bundle branch block, the focal blocks, and the septal repolarization.

Fig. 25

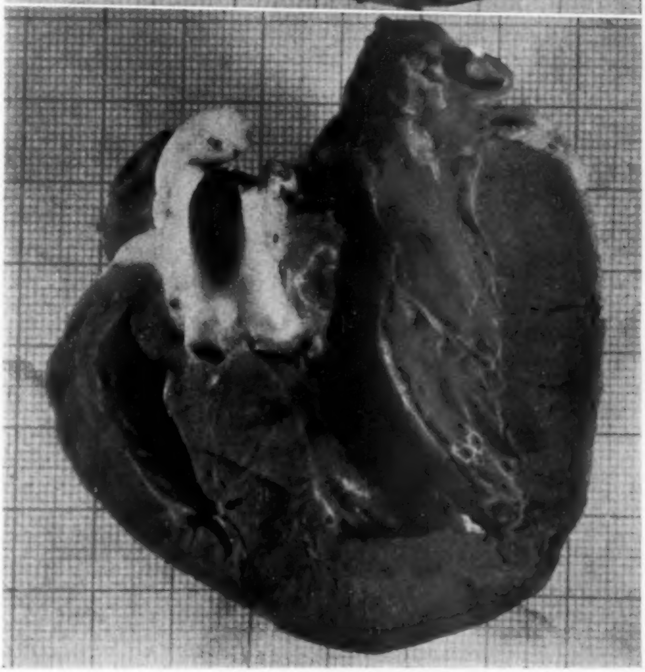


Fig. 26.

Fig. 25.—Anatomical section of the heart of a normal dog. It shows how it is possible to distinguish macroscopically on the interventricular septum the muscular portions corresponding to each one of the ventricles.

Fig. 26.—Observe in this section how the septum appears to be formed almost in its totality by the left ventricle. At the level shown by the arrow there is a defect in which the left ventricle actually forms the right aspect of the septum.

A. The normal Q wave: This has been referred to as a high septal vector after accepting Lewis' point of view that the region of the septum first activated is that lying immediately below the aortic valves. The initial positivity of the unipolar tracings recorded from the right ventricular cavity also has been referred to the same vector. Nevertheless, attention was called to the fact that this positivity is usually recorded near the apex of the right ventricle.

According to our results, the left septal surface is activated before the right. If the direction in which an impulse propagates can be represented by a vector, the septal activation may be visualized as a vector directed first from the left to the right and toward the trabecular zone and the apex of the right ventricle. Later, it is directed upward, probably toward the basal regions adjacent to the pulmonary and tricuspid valves. The Q wave would depend only on the first septal vector originating on the left septal surface and terminating at the septal fibers adjacent to the base of the anterior papillary muscle of the right septal surface.

Fig. 27.—Frontal sections of the heart at different levels; these sections correspond to the heart illustrated in Fig. 26. Each section shows from left to right the right free ventricular wall, the right ventricular cavity, the septum and small portion corresponding to the free wall of the left ventricle. It can be observed that in the middle section, there exists a considerable part of muscular fibers of the right ventricle that are differentiated from those of the left ventricle. In the section on the left, the same details can be observed as in Fig. 26, and in the section on the right, it is not possible to distinguish muscular fibers corresponding to the right ventricle.

B. The QRS complex duration in bundle branch block: It is generally accepted that the broadening of the QRS complex in bundle branch block is due to the time necessary for the activation wave to cross the septum and reach the injured branch below the blocked site. Our results are in contradiction to this point of view and suggest that the activation wave rapidly crosses the width of the septum formed almost wholly by the left ventricle.

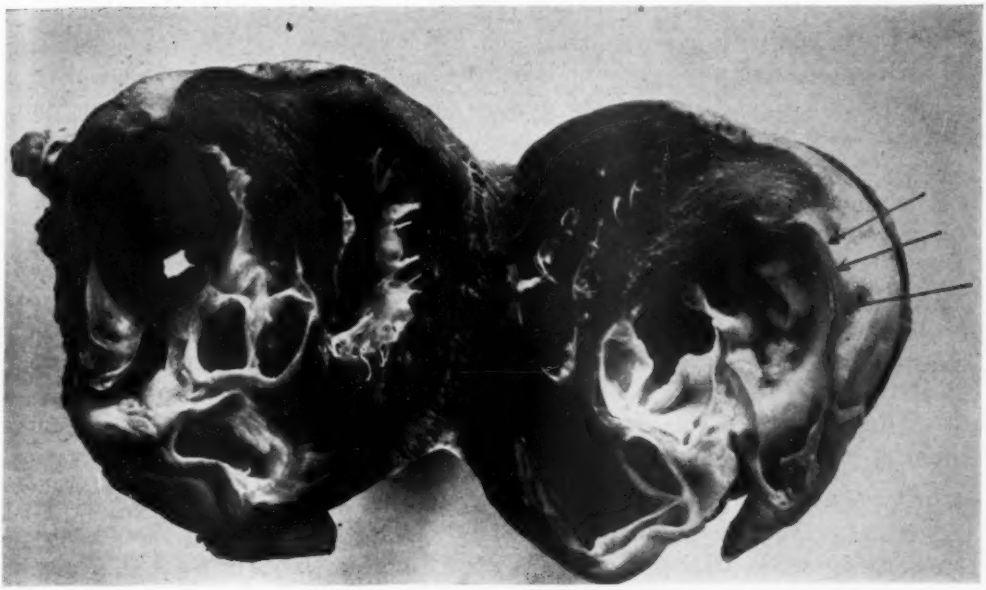


Fig. 28.—Horizontal section of the heart through a high level. It can be seen that the muscular fibers of the left ventricle have disappeared at a high and posterior level. The septum in this region seems to be formed mainly by muscular fibers of the right ventricle.

Fig. 29.—Section corresponding to the heart used in the experiment illustrated in Fig. 21. It shows a point on the left surface activated through the right branch of the bundle of His. The type of unipolar electrodes used in the experiments is shown.

The delay in activation following the block of either of the two bundle branches is limited to a very thin region. We suppose that this region extends in the septum from top to bottom, very close to the right septal surface and that its width is 2 mm. at most. The impulse, on crossing the width of the septum, does not suffer any delay until it crosses this region and passes to the opposite ventricle; that is, when it begins to activate the muscular fibers that depend on the blocked bundle branch.

In the right bundle branch block, the activation of the muscular fibers that depended on the left branch (the major part of the septum) is not delayed. Under these conditions the first part of the ventricular complex is not modified. On the other hand, in left bundle branch block, only a small part of the septum continues to be activated by the normal route. The major part of the septum is activated with some delay and in a direction opposite to the normal, that is, from right to left. This could account for the disappearance of the normal Q wave in V_5 and V_6.

C. The focal block: Some authors [15, 18, 19] insist that many tracings considered as characteristic of a bundle branch block are due to a delay of the activation wave along some portion of the free ventricular walls. The final slurrings of the QRS complex that appear mainly in the right bundle branch block would be due to such a delay. The vectocardiographic studies of Wilson's block suggest, according to the same authors, a focal block.

We have mentioned (Fig. 14) that in the branch blocks, there are portions of the septum that are activated very late, almost at the end of the rapid ventricular complex. This could explain the final slurring of the QRS complex and of the vectocardiogram. We do not deny the existence of focal block; actually, we have succeeded in producing it in experimental infarction of the myocardium. We feel however that it is premature to ascribe such morphologies to a delay of the activation in some regions along the free ventricular walls, as has been done by some authorities.

D. The septal repolarization: Up to now, the negative T wave of the left precordial leads in bundle branch block and left ventricular hypertrophy has not been referred to septal repolarization.

Our intracavity studies have shown that in some cases of incomplete block of the left bundle branch negative T waves are found not only in the precordial leads V_5 and V_6, but also within the cavity of the left ventricle.

Although we do not deny that repolarization of the free ventricular wall contributes to the morphology of the T wave inside the cavity and on the epicardial surface, its effect cannot be great, for if so, a positive T wave would be registered inside the cavity. But since this latter wave is negative, its negativity, as well as that of the epicardial T wave, must be attributed mainly to changes in repolarization in the interventricular septum.

On the other hand, by taking transeptal leads with electrodes at the same level, it is possible to demonstrate that in experimental blocks the process of repolarization is directed from the left to the right septal surface in blocks of the right bundle branch and in the opposite direction when the left bundle branch

is blocked. Thus, it is easy to explain why in these, the T wave can be negative in the cavity and on the left epicardial surface. The study of septal repolarization under different conditions would be interesting, as in the child's heart where it is possible that the proportion each ventricle contributes to the septum could be different from that found in the adult heart.

E. The late R wave of the right intra-auricular potential: It has been suggested earlier[9,16] that the positive deflection of the QR or Qr complex of the normal intra-auricular tracing could depend on zones of the septum that were activated late. The finding of septal regions in the dog that were activated 0.03 to 0.04 second after the onset of the ventricular complex and the fact that the process of septal activation is probably from below upward make such a suggestion likely.

In the right precordial leads, similar complexes can be recorded of the type QR, Qr in conditions with ventricular hypertrophy and major rotation of the heart. According to some authors, this positive late deflection could depend on some portions of the free wall of the left ventricle. Recently, Kossmann and associates[15] suggested that this deflection depends on the activation of the "crista supraventricularis." We have found that under these conditions, the tracings of the right precordial leads are very similar to those obtained by the right intra-auricular leads, and we suppose that because of the rotation of the heart and the growth or dilatation of the right auricular cavity the leads from the precordium give results similar to those obtained when the exploring electrode is located on the right auricular muscle. For the same reason, the late R of the intra-auricular tracing and the right precordial leads can depend on the activation of some of the septal portions, probably those near to the insertion of the pulmonary and tricuspid valves. On the other hand, this complex has been recorded in high portions of the septum (Fig. 15).

F. P-R interval or auriculoventricular conduction time: It is admitted that the P-R interval corresponds to the time needed by the activation wave to travel from the sinoauricular node to the origin of the branches of the bundle of His. This hypothesis is based on the assumption that the first ventricular region to be activated corresponds, according to the ideas of Lewis, to the upper part of the interventricular septum on its left aspect. Our results agree in general with this concept. They differ only in the location of the site where the ventricle is activated first, namely where the left bundle branch begins to ramify, that is, 2 or 3 cm. lower on the septal wall than indicated by Lewis.

The P-R interval represents the time required for the spread of the activation wave from the sinoauricular node to that portion of the septum which is activated first. As we have indicated, this normally is situated on the left ventricular surface of the septum. If, however, one cuts the left bundle, then the first portions of the septum to be activated are those adjacent to the base of the anterior papillary muscle. This activation occurs through its normal pathway, namely the right bundle branch, and with its normal time relationship, but activation at these points is normally about 0.01 to 0.015 second later

than on the left septal surface, and thus, theoretically, one would expect the P-R interval to become prolonged to this degree.

In several experiments we have actually found this lengthening of the P-R interval, thus confirming the theoretical expectations. However, it could have been due to an injuring of the auriculoventricular node while attempting to produce a left bundle branch block.

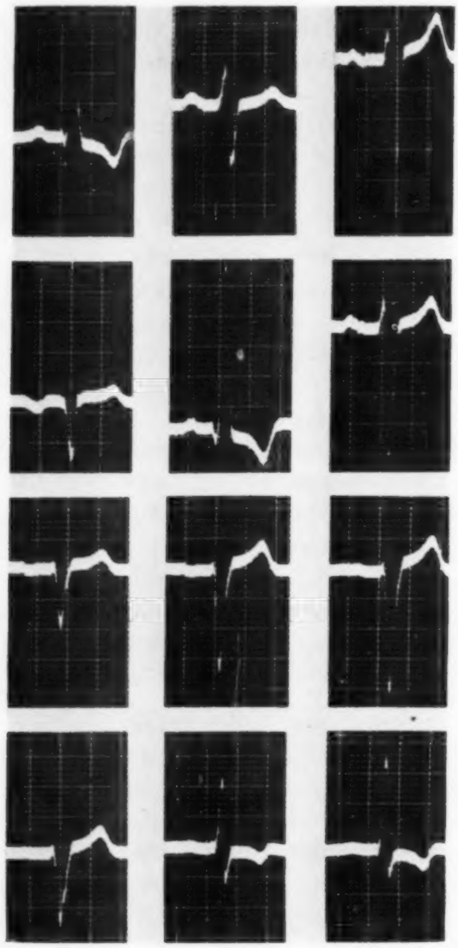


Fig. 30.—Electrocardiogram belonging to a patient with syphilitic aortitis. It is characteristic of left ventricular hypertrophy; the P-R interval was 0.20 second.

Studying the duration of the P-R interval in the human electrocardiograms, Moll[17] found that this interval was lengthened in 44 per cent of the cases of complete left bundle branch block and only in 6.6 per cent of the cases of right bundle branch block.

Reviewing our electrocardiographic records of those cases which presented during their evolution varying degrees of left bundle branch block, we found frequently that the P-R interval was lengthened as the degree of the blocks was greater (Figs. 30 and 31).

Those cases where the P-R interval is not lengthened during a left bundle branch block may be due to existence of zones high in the septum, the activation of which depends on fibers related to neither right nor left branches of the bundle of His. As mentioned earlier, if such pathways exist, their activation would be expected to occur early, and, hence, there would be no increase in the P-R interval.

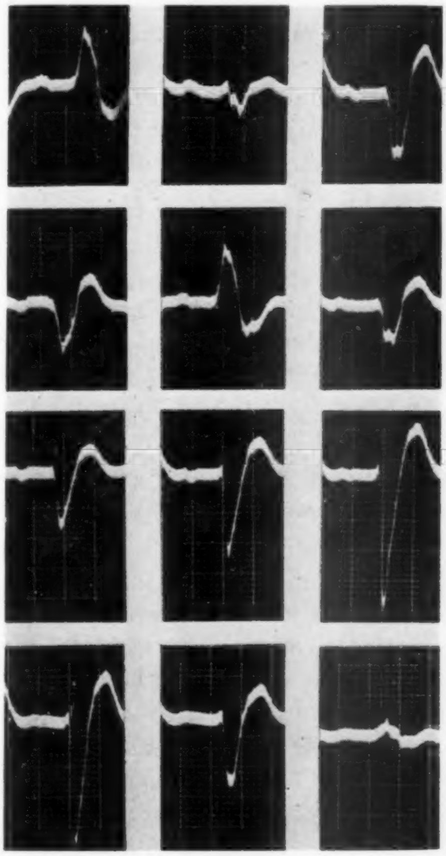


Fig. 31.—Electrocardiogram belonging to the same patient as in Fig. 30, showing a complete block of the left branch of the bundle of His. Observe the increase of the P-R interval to 0.28 second.

G. The intrinsic deflection: Recently one of us[16] suggested that the inferior vertex of the intrinsic deflection on the direct unipolar leads indicates the arrival of the activation wave at the place in contact with the exploring electrode. In some cases, however, it does not exactly correspond to the inferior vertex but to some point of the inferior one-half of the same deflection.

In this work, the preceding observations are newly confirmed. Thus, we have experiments like those of Fig. 13, in which the vertex of the major bipolar deflection corresponded almost exactly to the inferior point of the intrinsic deflection. On the other hand, in other experiments (Fig. 5), the point of reference of the contiguous bipolar lead corresponded approximately to the medial part of the intrinsic deflection.

If the unipolar lead was polyphasic, we always chose the last descending line as the intrinsic deflection. The same criterion has been followed in the clinical interpretation. This point of view is not arbitrary and has in its favor some theorical points of view referred to before and now some experimental facts.

In Fig. 15, the complex recorded in point *3* on the septum was Qr. It can be discussed whether in this case the intrinsic deflection was the first or second descending line. If the first descending line were the intrinsic deflection, point *3* would be activated before point *1*. This would not agree with the tracings obtained with bipolar leads which show that point *3* is activated 0.02 second later. On the other hand, when the inferior vertex of the second descending line on the unipolar lead of point *3* was taken, there existed a great concordance for the unipolar leads and the bipolar leads. In various other experiments, similar results were obtained.

SUMMARY

The process of septal activation in the dog's heart was studied by means of unipolar leads, distant bipolar leads, and bipolar leads using contiguous electrodes. The electrodes used in this study permitted the registration of the electrical phenomenon in any part of the septal surfaces and even in the interior of the septal muscle. The exact location of the site at which the lead was taken was determined precisely by post-mortem studies of the animal.

The following findings were demonstrated:

1. The mean process of septal activation is developed from below upward.

2. Extrasystoles produced in the epicardial surface of the apex of the ventricles cause a process of activation of the septum which proceeds from below upward, similar to normal activation. Extrasystoles provoked in the base of the ventricles produce a septal activation which proceeds from above downward, contrary to the normal process of septal activation.

3. The first region to be activated in the right surface of the septum is that portion in contact with the anterior papillary muscle. Those portions activated later are the part of the septum corresponding to the apex, the middle portions between the apex and the base septum, and, still later, those regions near the insertion of the atrioventricular valves and the pulmonary valves. These data are in accord with the distribution of the right branch of the bundle of His, since this branch descends enveloped in a sheath of connective tissue, and its first ramifications appear at the level of the base of the anterior papillary muscle. The remainder of the ramifications invade the septum from below upward.

4. The differences found between the times of arrival of the wave of activation to the first and last portions of the right surface of the septum fluctuate between 0.02 and 0.03 second.

5. In the left surface of the septum, the differences pointed out in 4 are much less and generally do not exceed 0.01 second. In the majority of the experiments, the first regions to be activated on the left side were those between the apex and the base. This is, in general, in accord with the appearance of the

first ramifications of the left branch, which begins to subdivide at levels higher than the right branch.

6. The greater part of the muscular tissue which makes up the septum behaves electrically as the left ventricle. For instance, when right bundle branch block is produced, the time of arrival of the wave of excitations is not altered, whereas with the production of left bundle branch block, there is a considerable retardation of the arrival of the wave of excitation. The muscular tissue, which behaves electrically as the left ventricle, approaches very closely the right surface of the septum, and there are even parts of the right surface that behave as left ventricle. The wave of activation reaches these portions rapidly (about 0.01 second). This makes it impossible to accept the concept that in bundle branch block the wave of excitation crosses the septum slowly (it was supposed in 0.04 to 0.05 second). All the evidence indicates that the retardation of the wave of excitation in bundle branch block takes place in the septum, but in a very small region, probably 1 to 2 mm., and very near the right surface.

7. In one case limited portions of the left septal surface were found which behaved electrically as the right ventricle. That is to say, there was no retardation of the arrival of the wave of excitation when left bundle branch block was provoked but a marked retardation when right bundle branch block was produced.

8. Anatomical cuts of the interventricular septum indicate that the distribution of the muscular fibers of the two ventricles is not incompatible with the findings related in paragraphs 6 and 7.

9. In two experiments we were able to show the existence of a small zone in the superior portion of the septum and in its muscular substance, whose activation was not delayed with either right or left bundle branch block. This zone corresponds approximately to the site where Mahaim has described the accessory paraspecific bundle. Nevertheless, in this respect, our experiments are few, and for the present we do not feel that we should draw any definite conclusions.

We are indebted to Dr. R. M. Calder for the great help that he gave us in translating this paper.

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THE QUESTION OF EXTRINSIC INTERFERENCE IN DIRECT LEADS

BRUNO KISCH, M.D.

NEW YORK, N. Y.

IT IS a basic fact in all electrophysiology that a living tissue plays a double role in the graphic registration of any kind of an electrogram: (1) the tissue may become a generator of electric charges; (2) it may serve as a conductor and, in this way, permit the registration of electric events generated at a distance from the exploring electrode.

In modern electrocardiography the prevailing tendency is to use a unipolar exploring electrode. This tendency brings up the question as to how much interference from extrinsic potentials influences the field beneath the exploring electrode. This problem is of the greatest importance in direct leads, where the exploring electrode is put on the surface of the heart in order to ascertain just what happens on the place of exploration. Similar problems, which of course have to be solved in a different way, arise in the taking of esophageal, intrabronchial, and chest leads. To have recourse in such cases to the laws of physics does not offer a satisfactory solution to the problems. It is not known to what extent short circuits and neutralizations of charges occur on the moist surface of a volume conductor.

Therefore, it seemed best to approach the problem empirically. This has been done, but only for direct leads taken on the surface of the heart.

METHOD

To find out how far the tracing taken on a certain spot of the heart is influenced through electric charges arising nearby, the following method was used: With a Sanborn Tribeam galvanometer two tracings were taken simultaneously. For each tracing Wilson's central terminal was used as the indifferent electrode and an isolated wire whose tip was covered by a thin layer of cotton moistened with the animal's blood as the exploring electrode. The surface of such an electrode in contact with the surface of the heart was about 1.0 to 4.0 mm.^{2} The two exploring electrodes were put at a short distance from each other (2 to 10 mm.), and the registration was made at high speed (75 mm. per second).

The investigations were performed on the dying hearts of different animals. The wave of contraction was creeping slowly over the ventricles so that with simple inspection it was possible to follow the path of such a wave and to find out its approximate origin. The main idea was that under such conditions it would take a certain time between the appearance of intrinsic deflections at each of the electrodes. Therefore, if the voltage is high enough, this may permit the registration of the electric current generated at electrode A by electrode B. The resting tissue may act in this case as the conductor.

From the Cardiographic Department of The Mount Sinai Hospital, New York.
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RESULTS

The first illustration (Fig. 1) shows two tracings taken simultaneously from the dying heart of a chicken. From the inspection of the heart it could be judged that a focus was still producing stimuli somewhere in the ventricles, apparently in the left ventricle, because a contraction wave was slowly and progressively creeping over the surface from the left to the right ventricle. The exploring electrodes were placed on both sides of the intraventricular sulcus, the one on the left ventricle (upper tracing) and the other on the right ventricle (lower tracing). The standardization for 1 mv. can be seen in the figure. The three strips of film were taken at short intervals. The rate slowed progressively. It can be seen that

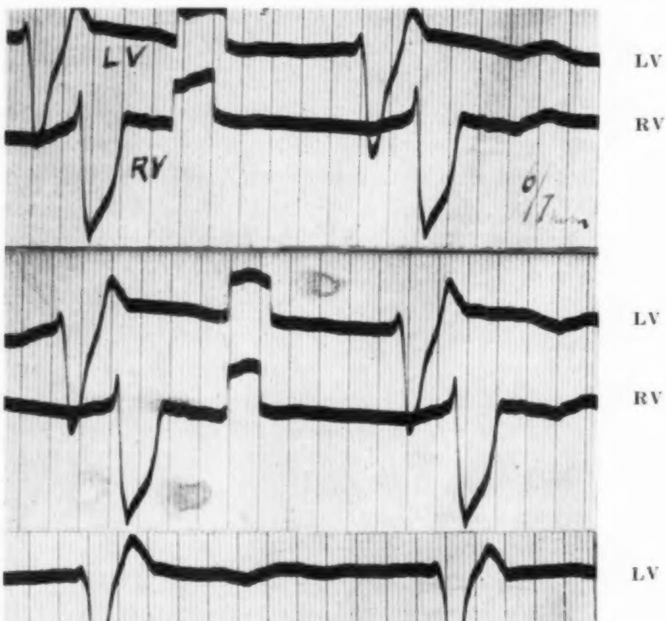

Fig. 1.

a cardiogram was recorded by each of the two exploring electrodes. The two electrograms were similar; only the R was smaller at the left than at the right ventricle, and the intrinsic deflection started at the right electrode in the first film 0.36, in the second 0.38, and in the third 0.44 second later than at the left ventricle. The distance between the two exploring electrodes being about 10 mm., the spread of the excitation wave in this dying heart was 25 mm. per second. While disregarding all details of the tracings, I would like to emphasize only the following: The voltage of each electrogram in strip 1 and strip 2 was about 3.5 mv. However, these deep negative deflections seemingly did not correspond to any similar or opposite synchronous deflection on the other tracing.

The second illustration (Fig. 2) is from the dying heart of another chicken. Again each tracing was taken with a Wilson central terminal. The exploring electrodes were placed on the middle of the left ventricle (upper tracing) and on the middle of the right ventricle (lower tracing), respectively. The distance between both electrodes was, in this case, about 20 mm. or less. The heart was still beating under the influence of the auricles. Their activity can be seen in the lower tracing, and less readily in the upper tracing. The lower strip of the tracing is an immediate continuation of the upper one. The standardization (1 mv.) of the upper tracing is 8 mm. and that of the lower one is 10 mm.

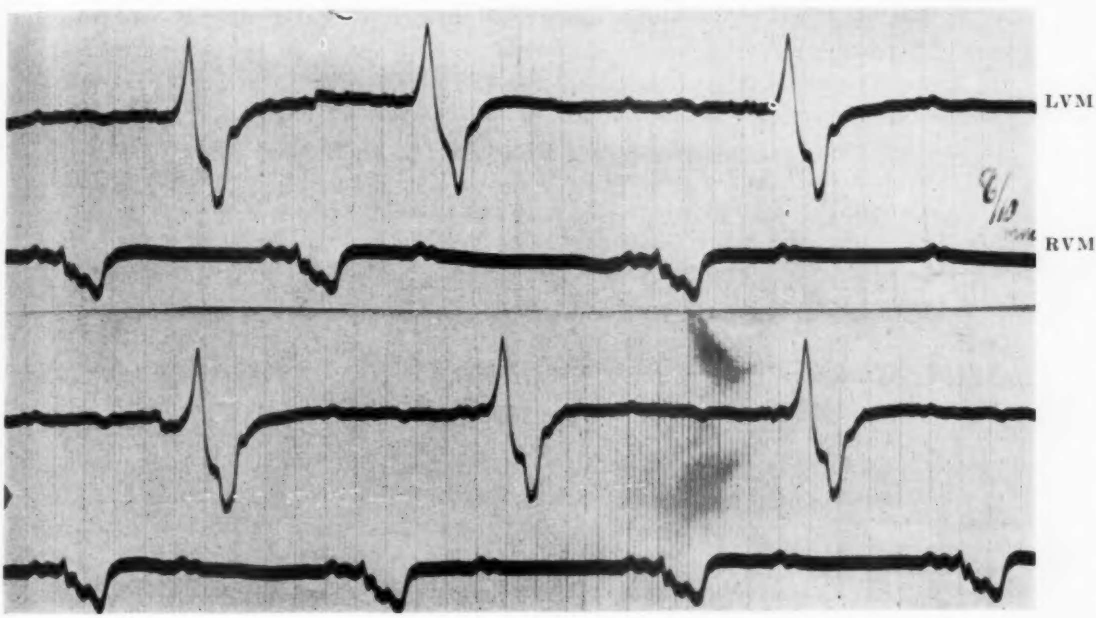

Fig. 2.

During the tracing an atrioventricular block started, and there was a certain irregularity to the auricular rhythm. The right ventricle responded to the auricular impulse always exactly after 0.02 second. Therefore, it is justified to suppose that there was an atrioventicular conduction present. However, inspection of the heart gave the impression that the contraction of the right ventricle was slowly creeping over to the left, so that probably the left ventricle got its impulses not via the atrioventricular conduction system, but by the impulse proceeding from the contracting right ventricle. In this case the time distance between the two intrinsic deflections was about 0.9 second. The distance of the electrodes from each other was about 20 mm. This resulted in a velocity of the excitation wave of about 25 mm. per second. The tracings, both from the right and the left ventricles, were bizarre in their form, but again the main feature seemed to be that the excursion of about 3.5 mv. of the upper tracing did not correspond to any simultaneous disturbance of the quiet base line of the right ventricle. This behavior contradicts to a certain degree what we usually expect from living tissue as a conductor of electric currents.

DISCUSSION

The simultaneous recordings of two electrograms from the exposed surface of the heart are experiments performed in our studies on the fibrillating heart.

Studying the mechanics of the fibrillating auricle or ventricle, with two or more tracings recorded simultaneously, always brings up the question as to whether the many excursions of the tracings recorded at one place are really only the intrinsic changes of the tissue near the electrode, or whether they are extrinsic interferences due to the activity of distant foci.

Thirty years ago I tried to solve this problem by burning a part of the surface of the heart and putting one electrode on the damaged place, the other on a normal area. No tracing was registered from the damaged place of the exposed surface of the heart. The method used, at that time, was one involving the use of Garten's differential electrode. The method used at present seems a more appropriate one, as the tissue is not artificially damaged. It is, however, tissue of a dying heart and therefore not the same as normal tissue. The tracings recorded indicated that, at least under certain conditions, changes in the voltage of one place on the surface amounting to 3.5 mv. may not influence a place at a distance of 10 mm. Whether short circuits on the surface are responsible for this behavior cannot be said, because sufficient experiments performed by physicists, on the distribution of potentials on the moist surface of volume conductors are not available. That similar conditions always prevail on the exposed surface of the heart can be expected if both exploring electrodes are not too near each other. The analysis of leads taken simultaneously from the exposed surface of the fibrillating heart thus would give a high degree of reliability.

The conditions are definitely different if the surface of the heart is not exposed, but in direct contact with the body tissue. In our second tracing the electrode, attached to the right ventricle, recorded the auricular activity. In this case the auricles were in direct contact with the body tissue as was the electrode, which was kept in place on the right ventricle by tissue.

SUMMARY

By simultaneous recording of two direct leads from the exposed surface of hearts with slowly progressive contraction waves, the following was observed: Deflections of the base line, amounting to a voltage of 3.5 mv. registered by one exploring electrode, were not accompanied by any simultaneous deflection on the tracing taken by another exploring electrode at a distance of 5 to 20 mm. from the first. The standardization of the registering galvanometers during the experiments was between 5 and 10 mm. per millivolt.

Under the experimental conditions described in this paper, no interference of extrinsic voltages was registered on the exposed surface of the heart.

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Clinical Reports

COMPLETE AURICULOVENTRICULAR BLOCK IN MYXEDEMA WITH REVERSION TO NORMAL SINUS RHYTHM ON THYROID THERAPY

EDWARD T. SCHANTZ, M.D.,* AND ALFRED W. DUBBS, M.D.**

ALLENTOWN, PA.

THE clinical entity "myxedema heart," as described originally by Zondek[1] and later by Fahr,[2] has become increasingly rare, no doubt due to the more prompt diagnosis of the hypothyroid state with institution of adequate therapy.

A number of excellent reviews of this subject have been made in the past, and it is not our purpose to present a repetition of facts already known. However, we would like to review briefly the literature on electrocardiographic changes accompanying hypothyroid heart disease and to report a case which we believe to be unique in the literature thus far, namely, a case of hypothyroid heart disease exhibiting complete auriculoventricular dissociation with reversion to regular sinus rhythm on thyroid therapy.

Zondek, in the first extensive study of myxedema heart, observed the following changes in the electrocardiogram: flat P waves, flat or inverted T waves, and low R waves. Ohler and Abramson,[3] in a series of thirteen cases of myxedema showing electrocardiographic changes, reported the following abnormalities: decreased voltage in all complexes, inversion of T waves in all leads, increased auriculoventricular conduction time in some cases, and return toward normal on thyroid therapy.

Means, Clark, and Lerman[4] in a review of twenty-four cases of myxedema heart corroborated the above findings and stated: "The electrocardiogram in myxedema is always abnormal. The most common abnormality is a flattening or inversion of the T waves, particularly in Lead II. In addition, abnormal axis deviation and small P and QRS complexes are common. On thyroid treatment many of the abnormalities disappeared wholly or in part."

Thatcher and White[5] described flattening of the T waves in Lead I with a QRS complex of low voltage as electrocardiographic manifestations of hypothyroid heart disease.

A number of abnormalities in cardiac rhythm have been cited in the literature. Auricular fibrillation is rare, but cases have been described by Ohler and Abramson,[3] Walker,[6] and Gant.[7] Auricular flutter was noted by Gardner.

From the Department of Medicine, Sacred Heart Hospital, Allentown.
Received for publication July 4, 1950.
*Resident in Internal Medicine.
**Chief of Medicine.

Ohler and Abramson[3] likewise noted paroxysmal auricular tachycardia as a complication of myxedema heart disease.

Disturbances in auriculoventricular conduction have not infrequently been reported in cases of hypothyroid heart disease. Davis,[8] Ziskin,[9] and Luten[10] all reported cases exhibiting prolonged P-R intervals which reverted to normal on thyroid therapy. Aub and Stern[11] noted complete auriculoventricular dissociation in a case of hypothyroidism. The administration of thyroid in this case, however, failed to alleviate the block but did increase the auricular rate.

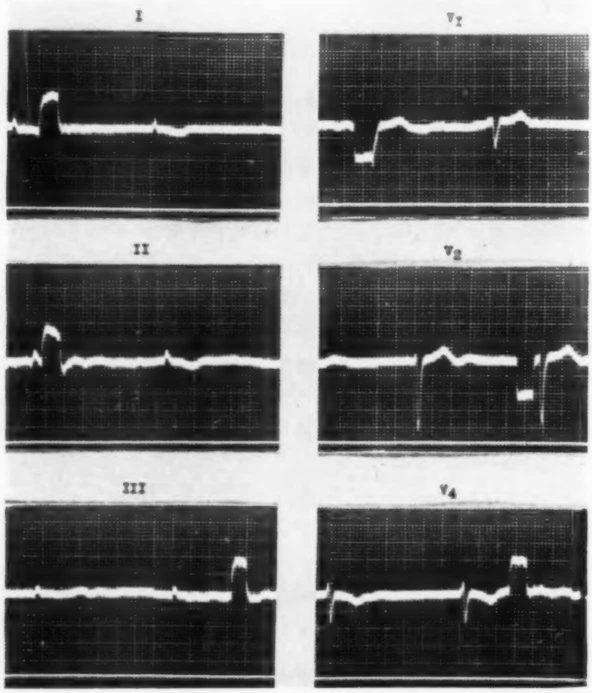


Fig. 1.—Electrocardiogram taken April 2, 1950, prior to thyroid therapy, showing complete auriculoventricular dissociation. The P waves are seen best in Leads II, V_1, and V_2. They are regular, equally spaced every 1.02 second, and bear no relationship to the QRS complex.

Thyroid preparations have been employed in the treatment of heart block of a nonmyxedematous nature. The action of thyroid in these cases is not clear. White[12] is of the opinion that it has an exciting effect on the ventricular musculature rather than decreasing the grade of block. Drake,[13] in 1928, reported the case of a 24-year-old white man with a complete heart block, the etiology of which was not clear. On thyroid therapy this reverted to a 2:1 block and finally to a normal sinus rhythm. Willius[14] described the use of thyroid in the treatment of Stokes-Adams syndrome in complete heart block. There was subjective improvement under this treatment, but apparently none of these cases were secondary to hypothyroidism and there was no electrocardiographic reversion to normal.

CASE REPORT

Mrs. E. S., a 67-year-old white woman, was admitted to the Medical Service of the Sacred Heart Hospital on March 31, 1950, with the complaints of feeling dizzy and weak. She stated that for the past several months there had been a gradual swelling of her hands, feet, and face. This was associated with fatigue and an intolerance to cold during the winter that necessitated the purchase of special wool-lined shoes. No other special complaints could be elicited, and the review of symptoms was essentially negative.

Physical examination revealed a white woman with a strikingly typical myxedematous facies. The face had an ivory pallor with a passive expression. There was puffiness beneath the eyes and smoothing of the nasolabial folds. The nose was broad, and the lips and tongue were thick, while the voice was husky and low pitched. The patient's hair was coarse, and her nails were dry and brittle. An arcus senilis was present. The thyroid gland was not palpable. Auscultation of the heart revealed sounds of poor quality. The rhythm was regular with a rate of 52 per minute. On percussion the area of dullness was definitely increased. The blood pressure was 132/70 mm. Hg. The hands and feet were thickened and swollen with a one plus nonpitting edema. The remainder of the physical examination was negative.

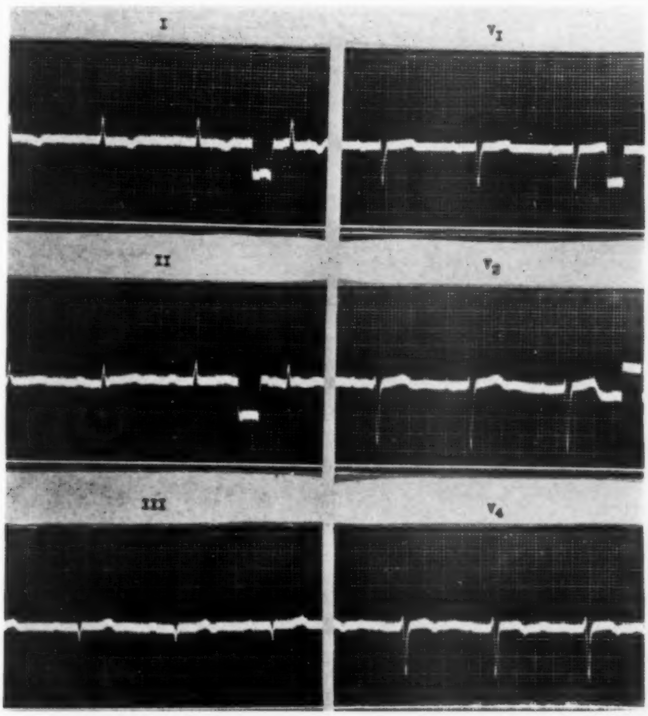
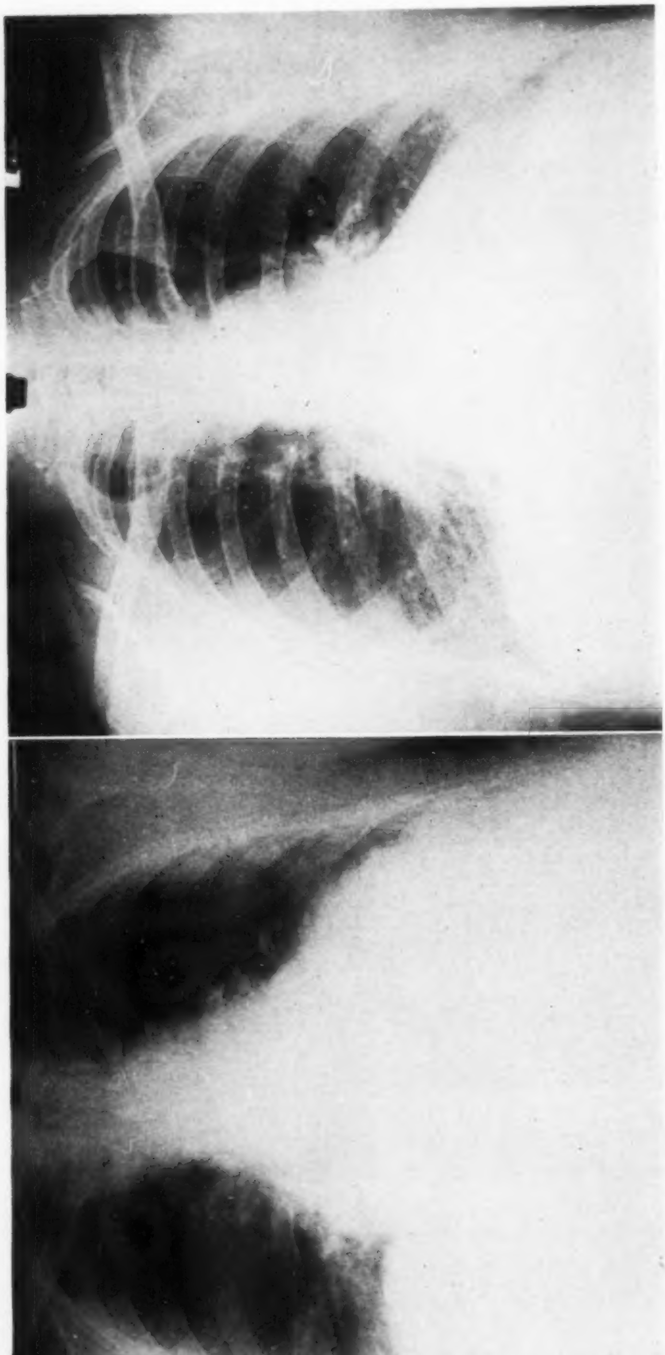


Fig. 2.—Electrocardiogram taken May 1, 1950, showing a Grade I auriculoventricular block. The P-R interval is 0.28 second. The QRS and T-wave voltage also is definitely improved.

Laboratory studies revealed the hemoglobin to be 75 per cent. The blood count showed 3,930,000 red blood cells per cubic millimeter and 6,800 white blood cells per cubic millimeter with 42 per cent lymphocytes and 58 per cent polymorphonuclear leucocytes. Urinalysis was essentially normal. Kolmer, Kahn, and Mazzini tests were all negative. Blood chemistry revealed blood urea to be 41.7 mg. per cent; blood urea nitrogen 19.5 mg. per cent; serum proteins 5.4 Gm. with 3.2 Gm. of albumin and 2.17 Gm. of globulin; cholesterol 251 mg. per cent.

A basal metabolism was done, and this was found to be −9 per cent. This was repeated, and a value of −5 per cent was obtained. It was felt that these did not represent the true readings as the tests were performed on the open ward.



A. B.

Fig. 3.—*A*, Roentgenogram of chest taken prior to thyroid therapy. *B*, Roentgenogram of chest taken May 9, 1950, showing decrease in cardiac silhouette.

An electrocardiogram (Fig. 1) taken on admission revealed the following: A complete (Grade IV) auriculoventricular block was present with a ventricular rate of 42 per minute and an auricular rate of 58 per minute. The axis was normal, and the duration of QRS complexes was 0.08 second; this complex was of low voltage as were the P waves, the latter being difficult to discern except in Leads II, V_1, and V_2. The ST segments were normal, but the T waves were inverted in Leads I, II, V_4, V_5, and V_6.

A roentgenogram of the chest (Fig. 3,*A*) revealed definite broadening of the cardiac silhouette. An abnormal density extending into the right upper lung field was interpreted as representing vascular shadows.

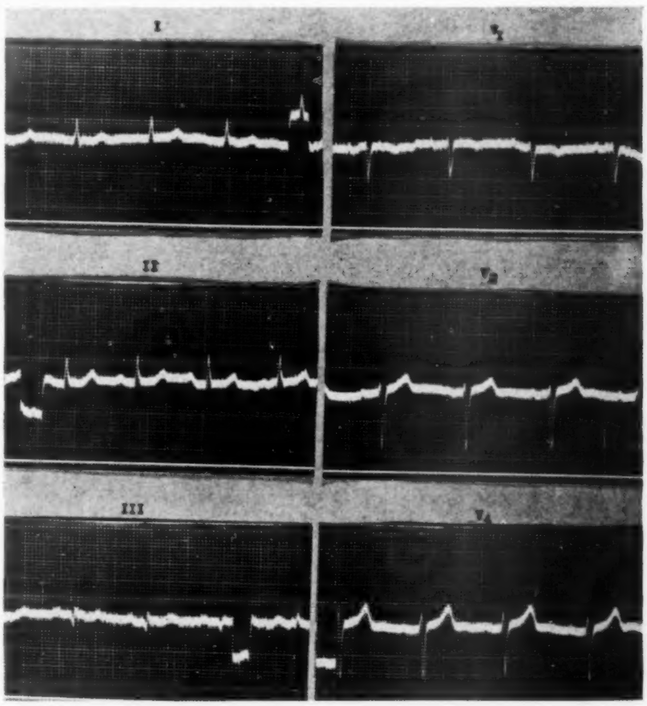


Fig. 4.—Electrocardiogram taken June 1, 1950. The P-R interval is now 0.2 second, and additional improvement is noted in QRS complexes and T waves. The T wave of Lead I is upright where formerly it was inverted.

In view of the typical clinical picture, along with the electrocardiographic findings of low voltage and T-wave changes, it was felt that this woman represented a case of hypothyroidism with the so-called myxedema heart. On April 6, 1950, she was started on 30 mg. of thyroid extract daily; this was supplemented with iron and vitamin therapy. After one week of this treatment, she noted marked subjective improvement, and her pulse increased to 72 per minute. On April 9, 1950, the dose of thyroid extract had been increased to 60 mg. daily, and on April 14 this was further increased to 90 mg. daily. The swelling of the hands, face, and feet gradually subsided along with the general feeling of fatigue. Her weight, which had been 150 pounds on admission, dropped to 146 pounds after three weeks of therapy.

An electrocardiogram (Fig. 2) taken May 1, 1950, showed the following: The previously complete auriculoventricular block had at this time reverted to a Grade I auriculoventricular block with a P-R interval of 0.28 second. The rate was 60 per minute, and the width of the QRS was 0.06 second. The height of the P waves and the QRS complexes had definitely increased, and the degree of T-wave inversion was less marked in Leads II, III, and V_4.

A re-examination of the chest (Fig. 3,*B*) on May 9, 1950, revealed decrease in size of the cardiac outline.

Her basal metabolism reading was repeated on May 1, 1950, with a result of +5 per cent being obtained. A repeat blood urea nitrogen test showed a drop to 17.2 mg. per cent with a blood urea of 36.8 mg. per cent.

By May 12 her weight had gone down to 144.75 pounds, and her pulse rate had increased to 70 per minute. Improvement, both subjective and objective, had been striking, and she was discharged on May 13, 1950. Thyroid therapy was continued.

On June 1, 1950, she reported for a repeat electrocardiogram (Fig. 4). This showed a rate of 75 per minute with shortening of the P-R interval to within normal limits (0.20 second). It was also noted that the T waves were of higher voltage.

COMMENT

An exact anatomic explanation of the above factors is difficult in view of the fact that autopsy material in cases of myxedema heart has been rather sparse. The fact that the abnormal electrocardiographic findings were particularly or entirely obliterated by thyroid therapy would certainly substantiate the generally accepted theory that there is a myxedematous infiltration of the cardiac muscle and nerve fibers, this being absorbed or dispersed when thyroid therapy is instituted. Schultz[15] described an homogenous infiltration in the cardiac muscle fibers that stained blue with hematoxylin but, according to him, differed somewhat from the myxedematous infiltration of the skin. Higgins,[16] in 1936, reported on two autopsied cases of myxedema heart; microscopically, the myocardium in these cases showed a marked degree of fibrosis.

In an effort to explain the electrocardiographic changes, Hallock[17] has advanced the possibility that the changes may be due to a slowing of coronary blood flow secondary to the flabby nature of the myxedema heart, as the changes noted frequently resemble those of coronary artery disease. The administration of thyroid would improve the coronary flow and rectify the electrocardiographic abnormalities.

Other possible interpretations of these changes are: basic coronary artery disease with coincident spontaneous evolution, and coronary artery disease, in part the result of myxedema with borderline conduction and improvement on thyroid therapy.

Prompt response to specific therapy would seem to indicate a direct relationship to the myxedema itself, whereas a persistence of P-R interval prolongation or an increase in duration despite thyroid therapy would suggest that the heart block was caused by independent cardiac disease.

Many other explanations[17] for the electrocardiographic changes have been offered without conclusive or consistent evidence. It seems most logical to assume that a combination of factors is responsible.

SUMMARY

1. The electrocardiographic findings of myxedema heart have been reviewed. These are, briefly: (a) low voltage of all complexes, (b) flattening and inversion of the T waves, and (c) reversion toward normal on thyroid therapy.

2. The various arrhythmias and disturbances in auriculoventricular conduction associated with myxedema heart are mentioned.

3. A case of complete auriculoventricular block with reversion to normal on thyroid therapy is reported.

4. Possible etiologic factors for the above changes are discussed.

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MYXEDEMA HEART, ATRIAL SEPTAL DEFECT AND HYPERTENSION, AND CONGESTIVE HEART FAILURE

F. GERARD ALLISON, M.R.C.P., F.A.C.P.

WINNIPEG, MAN.

FEW conditions are so satisfactory from a therapeutic point of view as "myxedema heart" if the precaution of initial small dosage of thyroid, outlined by McGavack, Lange and Schwimmer,[1] is followed to avoid coronary symptoms. The basal metabolic rate is of little value in the presence of congestive failure. The laboratory confirmation of the diagnosis may be made either by blood cholesterol estimation or, as in this case, by the newer method of protein-bound blood iodine described by Perry and Cosgrave.[2] This case is of interest because of the added findings of atrial septal defect and hypertension.

CASE REPORT

The patient was a white woman 63 years old. She was first seen on April 13, 1948, because of poor response to digitalis, Salyrgan, and salt restriction for supposed hypertensive heart failure which had been present for seven months. She complained of dyspnea on exertion and occasional mild nocturnal dyspnea. Orthopnea was present. She noted swelling of the legs and abdomen and increasing weight. There was sensitivity to cold and sleepiness, and a poor memory had been present since the onset of the dyspnea. There had never been substernal or arm pain. Past history was negative for rheumatic fever or chorea, although six years previously she had been told she had rheumatic heart disease.

She was slightly cyanotic and orthopneic. The neck veins were not distended. There was no pleural fluid. The liver was palpable four fingerbreadths below the right costal margin. There was no ascites, but there was pitting edema to the knees. The cardiac apex beat was in the fifth intercostal space in the midaxillary line, and the cardiac dullness was much increased to right and left. The pulmonary second sound was accentuated, and there was a rough systolic murmur, Grade 3, in the third and fourth intercostal spaces to the left of the sternum. The heart rate was 64 with an occasional extrasystole; the blood pressure was 190/115 mm. Hg but with no pulsus alternans. The skin was dry, and there were supraclavicular pads suggesting myxedema.

Fluoroscopy disclosed a football heart with hilar congestion. Some expansile pulsation in the left branch of the pulmonary artery suggested atrial septal defect. A barium drink revealed no left auricular enlargement in the right anterior oblique position. The orthodiagram measurements were: internal diameter of the chest, 22.7 cm. and transverse diameter of the heart, 18.3 cm. (Fig. 1).

The electrocardiogram showed a rate of 65 with occasional extrasystoles. It also showed right axis deviation. P-R intervals of 0.22 second, flat T_1T_5, digitalis effect, and low voltage of the QRS complex (Fig. 2). The protein-bound plasma iodine was 1.9 μg (normal, 4 to 9).

No attempt was made at pericardial aspiration to determine how much of the cardiac shadow was due to effusion. The well-marked apex beat in the midaxillary line was a point against a large effusion.

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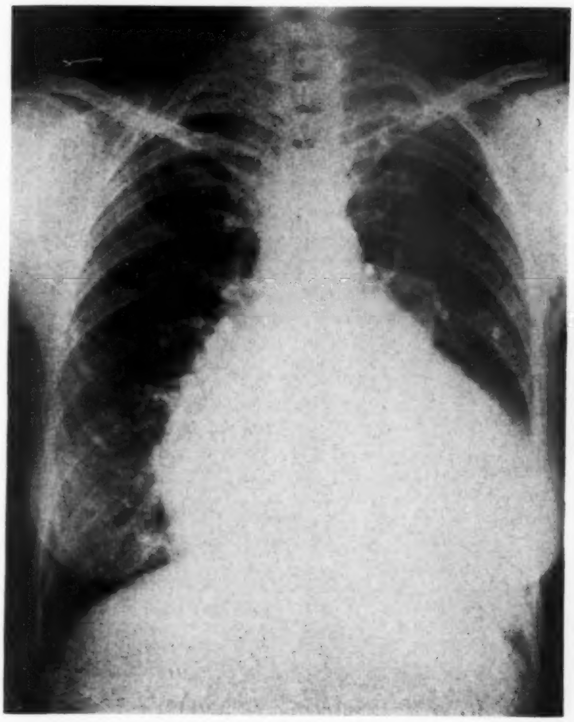

Fig. 1.—April 14, 1948, roentgenogram of chest before treatment.

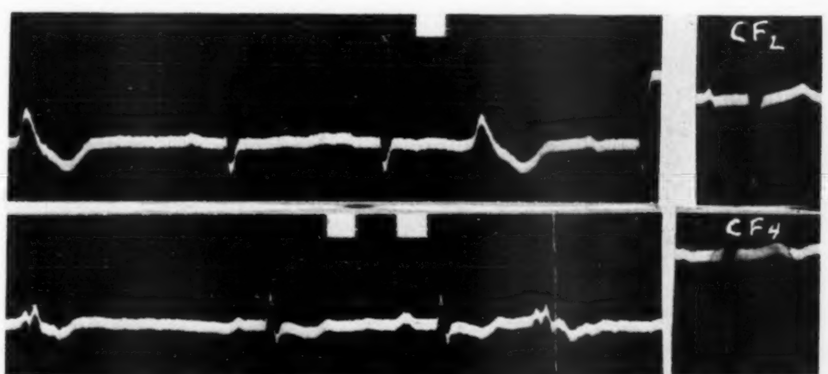

Fig. 2.—April 13, 1948, electrocardiogram before treatment.

Fig. 3.—Jan. 14, 1949, roentgenogram of chest (see text).

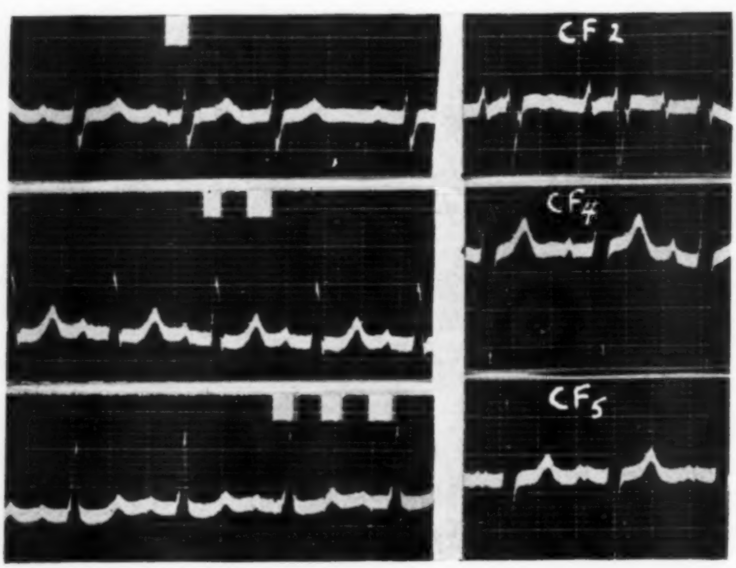

Fig. 4.—Jan. 19, 1949, electrocardiogram (see text).

Treatment.—The patient continued the former treatment, i.e., digitalis, 1 gr., twice daily, Salyrgan with ammonium chloride weekly, and salt restriction. There was added dessicated thyroid, 1/20 gr. daily, with the dose doubled every ten days until the dosage of 1½ gr. daily was reached.

Follow-up.—On Aug. 9, 1948, about four months after starting thyroid, the dyspnea and edema had disappeared. All treatment except thyroid was then stopped. On Jan. 14, 1949, no symptoms and no signs of congestive failure were present. The murmur was as before, and the blood pressure was 180/95 mm. Hg. Fluoroscopy showed marked expansile pulsation of both branches of the pulmonary artery. The cardiac diameter on orthodiagram was 12.5 cm., a shrinkage of almost 6 cm. (Fig. 3). The weight was 109 pounds, a loss of fifteen pounds. The electrocardiogram showed the rate to be 104 with an increase in voltage (Fig. 4). The basal metabolic rate was +19, and the protein-bound blood iodine was 4.7 μg.

DISCUSSION

The marked expansile pulsation of the pulmonary arteries, no increase in pulse pressure, and right axis deviation made the diagnosis of atrial septal defect relatively secure. Against patent ductus arteriosis were the normal pulse pressure, the axis deviation, and the absence of a continuous murmur. Against Eisenmenger's complex were the patient's age, the absence of cyanosis after the heart failure cleared, and the axis deviation. In a series of nine private adult patients clinically diagnosed as having atrial septal defect, there were two other patients over the age of 50 years, one of whom also had hypertension. This last was the only fatal case and came to autopsy following a massive cerebral hemorrhage. The septal defect was found to be 2 cm. in diameter. None of the seven normotensive patients had a systolic pressure over 125 mm. Hg. Three were in the third decade, two in the fourth, one in the fifth, and one in the seventh. These meager statistics were compiled to see if there was any suggestion that patients with atrial septal defect might be more prone to hypertension in later years. Bedford, Papp, and Parkinson,[3] Burrett and White,[4] and Taussig[5] make no mention of hypertension in this condition. Probably, the hypertension found in the two patients mentioned was coincidental.

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PARENTERAL QUINIDINE IN THE TREATMENT OF PAROXYSMAL AURICULAR FIBRILLATION

HERBERT BERGER, M.D.

TOTTENVILLE, N. Y.

THE treatment of choice for paroxysmal auricular fibrillation is generally accepted to be the use of sufficient quinidine to prevent the abnormal rhythm. The present report deals with a patient in whom this arrhythmia could be controlled only by large doses of this drug (4.6 Gm. daily). Unfortunately she suffered from ulcerative colitis which had been controlled for many years by psychotherapy, diet, antidiarrhetics, opiates, and, more recently, antibiotics. With large doses of quinidine it became impossible to control the colitis. On the other hand, the paroxysms of fibrillation became longer when the quinidine was discontinued and often were accompanied by circulatory failure.

CASE REPORT

The patient, a 56-year-old white woman, was first seen in 1945, complaining of frequent bowel movements often with mucus and/or blood. Following treatment with bland diet, psychotherapy, kaolin, opiates, antilysozymes, nonabsorbable sulfonamides, and more recently, other antibiotics, the colitis remained under fair control. The number of movements was reduced, and her nutrition was maintained. In January, 1949, she reported that on several occasions her heart would beat rapidly for periods of three to five minutes. There was some sense of oppression in the chest during these seizures, but she was comfortable when they disappeared. Since the attacks were infrequent, no medication was prescribed for them other than reassurance. By April of 1949 the paroxysms were more frequent, occurring several times a day and lasting somewhat longer. Despite many efforts to do so, it was not possible to see the patient during a paroxysm. She insisted that the heart was regular during these rapid periods, so a presumptive diagnosis of paroxysmal auricular tachycardia was made and treatment with quinidine was instituted. Since the unpleasant attacks continued, the dose of quinidine was increased until she was receiving in May, 1950, 3.3 Gm. daily. As this amount did not entirely prevent the paroxysms, it was still further increased until eventually she was receiving 4.6 Gm. per day on June 2, 1949. This dosage controlled the paroxysms for periods of two to three weeks.

Unfortunately, late in May, 1949, the colitis became much worse. For the next six months it progressed in severity in spite of all treatment. On many occasions the daily amount of quinidine was reduced, only to have the arrhythmia immediately return. In March, 1949, it was at last possible to obtain an electrocardiogram during a paroxysm; all attempts to do so for over a year had been unsuccessful. The electrocardiogram obtained in March, 1950, revealed the tachycardia to be auricular fibrillation.

Since the colitis was rapidly progressing, it was hoped to improve her condition by the use of digitalis. This, however, while salutary for the colitis, failed to reduce the cardiac paroxysms or to reduce the rate. The maintenance dose of digitalis as digitoxin was increased gradually to

From the Richmond Memorial Hospital and the Berger Clinic, Staten Island.
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0.5 mg. daily. This amount produced nausea and anorexia, further aggravating the loss of weight, but did not influence the cardiac status. In an effort to circumvent the gastric symptoms the digitoxin was given parenterally until the maintenance dose was gradually increased to 0.7 mg. daily over a period of two weeks. At this point nausea again occurred, but the cardiac paroxysms continued unchanged. After a period of three weeks without digitoxin, she was given 100 mg. of K-strophanthin intravenously during a paroxysm without slowing the rate. In April, 1950, combinations of digitoxin and quinidine were given in the hope of keeping the quinidine at a level that would not adversely affect the colitis (2 Gm. with 0.4 mg. of digitoxin by mouth daily). While this helped the colitis slightly, the paroxysms of tachycardia continued, became longer, and for the first time were associated with evidences of cardiac failure.

Quinine was substituted for quinidine, but even with 2.6 Gm. daily, when evidence of cinchonism appeared, the paroxysms persisted. Atebrin produced severe nausea with a dosage of 0.4 Gm. but did not affect the tachycardia.

Quinidine lactate intramuscularly produced considerable local pain and could never be given in sufficient amounts to control the heart. Intravenous use of this product was not attempted since it would not solve our long-range problem and further because of its inherent hazards.

Following a report of Gluck and associates,[1] an attempt was made to control the tachycardia with quinidine sulfate in propylene glycol.* After conference with Dr. Harry Gold of the Department of Pharmacology at Cornell, this treatment was instituted with 0.8 Gm. of quinidine sulfate in 3 c.c. of the diluent given every six hours intramuscularly. This immediately controlled the paroxysms, and the colitis quickly responded to the treatment which had been successful prior to the onset of the cardiac complication. An attempt was then made to reduce the dosage of the quinidine sulfate to the least possible amount that would control the paroxysms. For four weeks she was maintained satisfactorily on 0.6 Gm. every eight hours. On three occasions the interval between the doses was extended or the amount reduced. This was always followed by a return of the fibrillation.

The patient is at home and has learned to give herself the necessary injections. She has no paroxysms, and the colitis is well controlled. She has gained 3.6 kilograms, and she has no local discomfort from the injections.

SUMMARY

This is the first recorded instance of the control of paroxysmal auricular fibrillation with parenteral quinidine. When this drug was first introduced, it seemed that it would have a field of usefulness in controlling auricular or ventricular tachycardias or fibrillation in patients temporarily rendered incapable of oral administration. This report indicates its usefulness in those who are permanently unable to take quinidine by mouth.

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*Supplied by Marvin R. Thompson & Co., Stamford, Conn.

Review of Meeting

REVIEW

First International Congress of Cardiology, Paris, 1950

Part I

Demetrio Sodi-Pallares, M.D., and Jorge Espino-Vela, M.D.
Mexico, D.F.

THE following summaries represent one-half of nearly 150 papers presented to the First International Congress of Cardiology in Paris by Spanish or Portuguese authors. Summaries of the other one-half will appear later as Part II.

This work was undertaken as it was thought that, in all likelihood, the translation into English would render this material more easily accessible to English speaking authors. Furthermore, it was thought quite probable that in the past English speaking readers have unconsciously ignored Spanish or Portuguese publications due to language difficulties, and this has resulted in a lack of information. If such is true, the present group of summaries would fill one more purpose: that of supplying English speaking authors with a bibliography of the work being done in the reviewers' countries.

ANATOMY AND HISTOLOGY

1. It was shown in a group of 200 cases that pulmonary infarction[1] in cardiac patients is far more frequent than it was believed to be. In advanced cardiac patients, forced to remain at rest, pulmonary infarcts, whatever their size, occurred in one out or three cases and often proved fatal. It seems that the main factor favoring the production of pulmonary infarcts is heart failure. A great number of small pulmonary infarcts are not diagnosed as they pass unnoticed in the midst of the symptomatology of cardiac failure. The best data for the diagnosis are not physical findings, but the electrocardiographic findings, which bespeak of the acute dilatation of the right cavities. Unfortunately, only one-third of the patients showed a typical image; one-third of the findings were subject to discussion, and the remaining one-third did not show electrocardiographic modification. The roentgenogram was decisive in a limited number of cases.

2. Vascular brain lesions found in 750 autopsies were studied,[2] excluding cases of "rheumatic encephalopathy," which formed 10.8 per cent, cerebral

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softening with no demonstrable vascular lesions (2.66 per cent), and those of uremia (3.46 per cent).

Sixteen cases of embolism due to rheumatic heart disease were studied. There were no cases of embolism of different origin. There were thirteen cases of thrombosis of which seven occurred in rheumatic heart disease, four with arteriosclerosis, and two with hypertension. The prevalence of rheumatic patients was due to the great incidence of this disease in Mexico. Among forty-four cases of hemorrhage, seven were in rheumatic patients, seventeen were in arteriosclerotic or hypertensive patients, and seven had doubtful origins. The remaining thirteen were slight and without clinical manifestations; they were taken into consideration because of the value they have in contraindicating the use of anticoagulants.

3. Microglia reactions of the central nervous system were studied in patients with acute rheumatism.[3] During periods of exacerbation microglia alterations were observed which might be (a) diffuse and slight in the cerebral cortex and the central gray nuclei, (b) perivascular, due to microscopic hemorrhages, or (c) nodular, probably of syphilitic origin. Diffuse alterations consisted in loss of spiculae of the prolongations of the Ortega cells and a considerable increase in volume of somatic cytoplasm. Alterations due to hemorrhages were characteristic because of the formation of granulo-fatty bodies. Specific nodules were formed mainly by branched microglia, and they represented very likely formations similar to Aschoff's nodules.

4. Vascular alterations[4] seen in the heart valves of patients with acute rheumatism are essentially proliferative, and they are accompanied by specific histologic changes only during initial stages of evolution. Three periods may be distinguished in this vascular proliferation: (a) acute, with dilatation of the lumen; (b) subacute, with proliferation of the intima; and (c) chronic, with sclerosis. During the acute period, endothelial cells increase in volume, whereas the media and the adventitia may show small Aschoff-type granulomas. The second period is characterized by multiplication of the endothelial cells, while the media and the adventitia are distended and thinned. The important aspect of the third period is the neoformation of argyrophile precollagenous fibers persisting until the vessels are surrounded by the collagenous tissue of the valvular scars.

5. The case of a patient was reported[5] in whom rupture of a hydatid cyst of the right auricle gave rise to a metastatic pulmonary echinococcosis. When the left pulmonary artery was obstructed, an aneurysmal dilatation was produced with a local intra-aneurysmal echinococcosis and hydatid emboli made of vesicles and portions of membrane at the subdivisions of the artery. Also, a chronic pulmonary hypertension, chronic hydatid cor pulmonale with great hypertrophy of the right ventricular wall, and resulting intractable heart failure were produced. Due to the perfect integrity of the pulmonary artery and its branches, this case proves that prolonged deleterious actions on one of the main branches of the pulmonary artery may give rise to a chronic hypertension of the pulmonary circulation.

CLINICAL PAPERS

1. A paper was read discussing the auscultatory signs of regurgitation and stenosis of the tricuspid valve.[6] The following points were emphasized: (a) tricuspid lesions were more frequent than usually admitted, and (b) the auscultation signs giving the clue to the diagnosis were the reinforcement on postinspiratory apnea of tricuspid phenomena in contrast with the diminution that this produces for mitral and aortic lesions. Such is true for the systolic and diastolic murmurs as well as for the opening snap of the tricuspid valve. This work was presented with a series of phonocardiograms and intracavity pressure tracings. Physiopathology of the findings was discussed.

2. A paper was presented on the cardiac sequelae of undulant fever.[7] Fifty previously normal patients who had this disease were studied at the time when there were no signs of the activity of this ailment. The patients' ages varied between 20 and 41 years. Clinical examination, electrocardiography, x-ray examination, and biologic tests were done on all of them two years after the acute stage of the disease. Thirty-three per cent of the patients proved to have evidence of organic myocardial disease. Electrocardiographic changes were widening of the QRS complexes (0.12 second), notching of R and S waves, negative displacement of RT segments, and low T waves. Eighty per cent of the patients, on the other hand, showed abnormal tracings. Radiologically, there was increase in the heart size in 50 per cent of the patients with organic heart disease. None had important congestive heart failure nor were any valvular or pericardial lesions found.

3. Chagas' disease was the subject of an experimental study[8] on dogs of different ages. This study was controlled by biologic, radiographic, electrocardiographic, and clinical examinations. It was concluded that there exists in Mexico a species of schizotrypanum which is highly pathogenic in dogs, producing in them typical Chagas' myocarditis. It was also concluded that the disease has not been accurately controlled in Mexico, even though in some regions 80 per cent of the infection by triatomas has been discovered with 60 per cent of positive Guerreiro-Machado reactions. The picture exhibited in infected animals was that of dilatation of the heart cavities, especially the right. Electrocardiographic disturbances included sinus tachycardia, auricular paroxysmal tachycardia, extrasystoles, and varying degrees of block. Clinically, loss of weight, asthenia, weakness, irritability, anorexia, fever, dilated abdomen, melena, and convulsions were observed. At autopsy, heart enlargement, ascites, and meningeal congestion were present with, histologically, severe acute myocarditis with intramyocytes and a few leishmania. Therapeutic action was tried with the use of ACTH.

4. A new cardiological entity was presented, Chagas' heart disease,[9] with a previous introduction in the way of a discussion of the position of Chagas' disease in the nosology[10] with the general description of the chief clinical aspects of the disease.

With the analysis of the available clinical, electrocardiographic, pathologic, and experimental evidence of this disease, the following conclusions were reached:

(a) There are some endemic regions in Brazil with a high incidence of chronic isolated myocardial disease in young or middle-aged people who almost invariably exhibit positive laboratory tests. (b) The clinical picture is absolutely typical, allowing the clinician to discard other etiologic factors. There are two forms of heart disease related to *Schizotrypanum cruzi* infection: acute Chagas' heart disease, which is usually found in children, and chronic Chagas' heart disease, which, as a rule, is a late consequence of the infection and is found mostly in young or middle-aged adults. (c) Electrocardiographic changes are also typical of the ailment. (d) Pathologic studies reveal the presence of a specific, acute diffuse myocarditis with leishmania in the stage of *Trypanosoma cruzi.* (e) Experimentally, dogs infected with *Schizotrypanum cruzi* show a type of heart disease quite similar to the human aspects of Chagas' disease.

5. Another paper was presented in which ten cases of congestive heart failure of doubtful origin were discovered through laboratory tests[11] to be due to Chagas' disease. Clinical, electrocardiographic, and radiologic evidence makes the picture easy to misinterpret as rheumatic heart disease, myocardial sclerosis, and cardiac neurosis. It was stated that the disease was seen in the country for the first time, and ten out of fifteen suspected of having the disease proved to be so infected.

6. The subject of undulant fever in relation to heart disease was presented in a paper[12] in which an analysis was made from the statistical, clinical, electrocardiographic, radiologic, humoral, and therapeutic standpoints. The author describes a cardiovascular form of brucellosis.

7. A study was presented of the clinical, roentgenologic, and electrocardiographic features of seventeen patients, all male, with beriberi heart disease in heart failure of various degrees.[13] There were three fatal cases in which necropsy confirmation was obtained. The main etiologic factor was chronic alcoholism.

Edema, dyspnea, and polyneuritis were among the prominent clinical features. X-ray examination revealed a definite reduction in heart size in several cases, some of which did not return to normal in spite of intensive treatment with thiamin chloride. Electrocardiographic changes were observed mainly in the T wave, i.e., increase in width, inversion, and so forth. Clinical improvement was not necessarily followed by improvement of the tracings. No rhythmic disturbances or conduction defects were seen. Examination of the serum revealed low plasma protein levels in a few cases. Anemia was rare and slight. Treatment with thiamin chloride (Vitamin B_1) was followed ordinarily by rapid improvement of the heart failure.

8. A paper was presented dealing with a study of atmospheric temperature and humidity.[14] The authors established the normal range of these factors for healthy and sick individuals, and they insisted on necessary precautions for cardiovascular patients when oxygen tents or chambers are used or special atmospheric conditions are created in their rooms. These precautions will avoid unnecessary respiratory complications (overdryness or coldness of the air) and will enhance a favorable course of the disease.

9. A study of three cases of posttransfusion myocardial infarction was presented.[15] In all three the blood groups were carefully investigated, and no blood incompatibility could be blamed for the outcome. The patients were adults, two being hypertensive, the other having angina pectoris. Diagnosis of the fatal complications was made clinically and electrocardiographically. The authors discussed the pathogenesis of this complication and gave advice as to the precautions to be observed.

10. Five cases of congestive heart failure due to scleroderma were presented[16] with clinical, radiologic, and electrocardiographic examinations. All were adults and had a chronic dermatological condition. The authors believe all cases of scleroderma should be carefully studied from the cardiovascular standpoint. They feel that heart involvement may be associated with the skin lesion, but it may occasionally be primary.

11. Chronic cor pulmonale due to silicosis was studied[17] for ten years in miners. The aspect of the pulmonary silicosis is granulomatous and not pseudotumoral. The hearts of these patients were studied from the clinical, functional, radiologic, hemodynamic, anatomic, and histologic standpoints. The right side of the heart is always hypertrophic but not in congestive failure. These patients die (a) of secondary tuberculosis, (b) of silicosis, which reduces the respiratory function to a fatal level, and (c) through heart involvement. Yet the author has never seen the latter complication. In fact, the condition known as chronic cor pulmonale was quite slight even in the last stages of the disease.

12. Bronchogenic subacute cor pulmonale was studied[18] from the physiopathologic standpoint, and the authors concluded that these cases showed alveolar hypoventilation, anoxemia, hypercapnia, hyperlactacidemia, increase of the respiratory minute volume, venous hypertension, increased blood flow, and hypervolemia, all of reversive nature.

13. The clinical, radiologic, and laboratory (especially hemorespiratory function tests) bases for the diagnosis of "black cardiacs" of Ayerza[19] were given. The authors reviewed briefly the existing literature.

14. A case of pseudo-Hutinel-Pick's disease was presented.[20] It was actually a case of severe mitral stenosis with calcified valve with ascites needing frequent tappings. Some x-ray and electrocardiographic findings suggested the existence of the syndrome, although, clinically, enough diagnostic elements were not present. Autopsy disclosed no pericardial involvement but showed the type of liver found in Hutinel-Pick's disease. The author discussed the resemblance of the disease to mitral stenosis and pointed out the common features of these two diseases with Concato's disease.

15. A study was presented of the cardiovascular mechanisms of syncope as produced by cough.[21] The author reviewed the different mechanisms suggested for production of syncope through cough and, having carefully studied several illustrative cases, concluded that cough may bring about syncope in the following cases, which indicate the circulatory causes involved. These were: (a) cough due to physical effort in certain heart conditions: aortic stenosis, coronary insufficiency, and congestive heart disease; (b) cough through intrathoracic increased pressure as a cause of syncope by diminution of minute volume,

seen in ventricular paroxysmal tachycardia or in primitive orthostatic hypotension; (c) cough through anoxemic cerebral congestion, chronic cor pulmonale, Ayerza's syndrome, and some congenital heart diseases (anoxemic syncope); (d) cough producing stimulation of different sensitive intrathoracic or carotid regions as a cause of cardiac syncope of reflex origin; (e) cough with secondary hyperventilation (acapnial syncopes); and (f) cough in epilepsy (epileptic syncope).

16. A paper was read under the name "On the Oedematous Periphlebitis Developing Cephalad to Acute Venous Thrombosis and the Stenosing Phlebitis That May Follow."[22] The author thought he described a new entity, whereby, after an acute episode of phlebitis, there exists a condition of edematous periphlebitis which undergoes organization and surrounds the vessel with connective tissue. This gives rise to a strangling process of the vein; the intima adheres and the process causes a firm closure of the lumen of the vein. These aspects are found from the fifteenth to the thirtieth day after the onset of the acute process, being recognized on operation or at autopsy. The author insisted on the uselessness of operation for thrombectomy after such a period and, on what may be expected in such cases, of clinical and phlebographic investigations.

17. The problem of the diagnosis of the retroperitoneal rupture of aneurysms of the aorta[23] was reviewed. The author studied six cases of ruptured aortic aneurysm seen over a period of twelve years among 151 cases of aortic aneurysms, twenty-four of which were abdominal. He gave a history of his cases and summarized his conclusions.

18. The syndrome of Lériche[24] or chronic aortoiliac thrombosis was studied in six cases illustrated with aortographs. The authors gave the clinical picture which usually included sexual weakness and absence of arterial pulsation in the lower extremities. They presented their aortographs taken with the Dos Santos technique, injecting the opaque substance directly into the aorta. They have never had any accidents due to the route or the substance used. On the contrary, their patients have experienced improvement following examination.

ARTERIAL HYPERTENSION

1. Spanish speaking authors presented to the First International Congress of Cardiology a series of papers on arterial hypertension. They spoke of the secretion by the arterial wall of a substance which combined with another pre-existent in the plasma gave rise to a hypertensive principle.[25] A series of experiments in animals gave strength to the idea that the pre-existing plasma factor is the hypertensinogen or angiotonin. Investigations have been carried out on the concentrations of renin in normal and hypertensive kidneys, and no appreciable differences have been detected.[26] They found that ischemia increased the amount of renal renin, but this was prevented by renal denervation in some animals. They also found that anoxemia did not increase the amount of renal renin, but, on the contrary, it was increased in hypertension following shock.

2. Studies have been made on the relation between water and electrolite metabolism with arterial hypertension,[27] and it was found that in all animals

(rats) in which arterial hypertension was produced through removal of both kidneys, there was an increase in the volume of extracellular fluid and the blood volume. It was also found that there was a correlation between the increase of extracellular fluid due to water and salt retention and the frequency of arterial hypertension produced by Doca or by unilateral perinephritis.

3. Hypotensive action of vitamin K[28] was proved, and 31 per cent successful results were recorded. The remaining patients experienced subjective improvement without lowering of their pressure. Vitamin K had no deleterious effect on the body, and its action on serum cholinesterase was variable.

4. Comparative studies were made between hypertensive and normal subjects on capillary fragility, using negative and positive pressures.[29] Results according to the individual and the method used were presented; also, the influence of certain substances such as thiocyanate and rutin on capillary fragility was established. Thiocyanate did not increase capillary fragility in hypertension, nor did the authors find that rutin had a beneficial action on this disorder. No relation was established between the degree of capillary fragility and the incidence of retinal hemorrhages or vascular cerebral accidents.

5. From the therapeutic standpoint of hypertension, it has been said that medical treatment is practically without effect; it was emphasized, on the other hand, what good results were obtained with surgical treatment (sympathicolytic) in 100 cases of hypertension,[30] especially in particularly severe cases or in heart failure. Arterial normal pressure tables have been made according to age, sex, and biologic type of 5,000 normal individuals.[31]

CONGENITAL HEART DISEASE

1. The study of congenital heart disease was undertaken enthusiastically, and numerous contributions were made. A paper on patency of the ductus was read from the hemodynamic, electrocardiographic, and clinical[32] aspects of eleven atypical cases. Cases with pulmonary hypertension of considerable degree were studied with special reference to the differential diagnosis with other congenital cardiac lesions.

2. A new syndrome with congenital cyanosis was described in a 16-year-old individual with patency of the ductus and arterial pulmonary hypertension.[33] This diagnosis was confirmed by catheterization and angiocardiography. An interesting hemodynamic study on patency of the ductus in eight patients whose clinical diagnosis was impossible was also read. In these cases catheterization was done in order to reach the correct diagnosis. All of them had an unusually high pulmonary pressure. Four had cyanosis.[34] Finally, a new diagnostic method was described for the diagnosis of patency of the ductus by means of the catheterization of the ductus itself. Twenty-five such cases were reported.[35] In this method a radiologic typical image of the passage followed by the catheter was presented, and the study of pressure curves was also quite demonstrative. On the contrary, the analysis of gases was frequently misleading.

3. Angiocardiographic studies were done in congenital heart patients whose ages varied between 8 days and 13 years.[36] In this study it was stated that the jugular veins need not be used and that the veins of the forearm suffice. It

was concluded that this is an excellent diagnostic method as confirmed by some necropsy cases. It was stated also that it is a method that is well tolerated and has not given any important complications.

4. A study on the value of catheterization in congenital heart disease as a diagnostic method in septal malformations and patency of the ductus was presented.[37] Clinical, gas analysis, and catheterization data were analyzed. Radiologic and electrocardiographic data were also resorted to as comparative values.

5. A study on the clinical diagnosis of the different varieties of interauricular communication from the hemodynamic standpoint[38] was presented following a classification which groups them with (a) pure arteriovenous shunt, (b) pure venous arterial shunt, or (c) mixed shunt. Clinical, radiologic, and electrocardiographic data were analyzed at the same time.

6. A case of tetralogy of Fallot with poststenotic dilatation of the pulmonary artery was studied. It was confirmed with catheterization and angiocardiography.[39] Fluoroscopy elements for diagnosis with Eisenmenger's complex were presented.

7. Catheterization studies were reported in different types of congenital heart disease, especially considering the pressure in the pulmonary veins and the oxyhemoglobin saturation in the blood of these vessels.[40] Thirty cases were studied with and without other malformations. Since the figures for the oxygen saturation of the blood in the pulmonary veins varied according to the vein, either superior or inferior, and according to the day of the examination in the same individual, it was concluded that determinations of these values do not give certain information, as some studies lead one to believe, as to the extent of the flow through the lungs. A discussion on the radiologic means of finding the pulmonary veins was presented, and the results of the pressures found in them were given.

8. Cavities of the left side of the heart have been catheterized through an interauricular communication or by an artery.[41] The study of the curves of the left auricle and those of the right auricle gives two types of tracings. One is obtained when the catheter is near the mitral valve, and it expresses especially the period of isometric contraction of the left ventricle; the other curve corresponds to a distant place from the mitral valve. The tracing of the left ventricle is easily interpreted if referred to a phonocardiogram and an aortic simultaneous tracing. The phases described by Wiggers are easily seen: isometric contraction, expulsion, protodiastole, isometric relaxation, and rapid filling. The morphology of the arterial pressure curve was also studied from the center to the periphery.

9. Studies of venous pressure in man were done by means of intracardiac catheterization,[42] and conclusions on the pressure figures at each level were reported. The 0 level is determined accurately. Support is given to the thoracic collapse of the vena cava in normal subjects. The venous pressure was also measured in normal subjects, and the normal figures were given for upper and lower levels.[43] The role of thoracic collapse for the subclavian vein and the inferior vena cava was discussed as were also the causes that tend to separate the

levels of pressure in lower and upper extremities and the mechanisms of action of the tests of Müller and Valsalva.

10. A study was done on the circulation time, venous pressure, volemia, and minute volume standpoints in rheumatic mitral stenosis.[44] It was concluded that in such cases congestive heart failure may manifest itself early through increases of venous pressure, which, according to the authors, would serve as a protective mechanism trying to oppose itself to the mitral obstacle.

11. A number of patients clinically diagnosed as having aortic stenosis[45] had been catheterized. This study revealed no pressure changes between the left ventricle and the aorta, for which reason it was inferred that the aorta valves may be damaged without producing any hemodynamic changes in the left ventricle.

RADIOGRAPHY AND ELECTROKYMOGRAPHY

1. This new method of investigation has been widely utilized. In one paper[46] the circulatory time of the pulmonary circuit in each lung for the arterial, capillary, and venous circulations was studied. Normal subjects and some patients with physiopathologic lesions in different stages were investigated. Three interesting papers were presented on the same method.[47,48,49] The first referred to the form and amplitude of the normal left ventricular electrokymogram done on sixty-two adults. The wide variations of oscillations observed were mentioned, and it was stated that they depended fundamentally on volumetric, postural, and transparency changes in different portions of the heart. The authors analyzed the technique employed and described three types of well-individualized curves which they add to the four basic types of Boone and co-workers. They described the characteristics of shape and duration of systolic retraction and diastolic dilatation. The second paper referred to chronometry of the left ventricle, the aorta, and the pulmonary artery as well as that of the hilar shadows and pulmonary fields in sixty-two normal adult subjects. With this method the duration of the isometric period was measured in 70 per cent of the subjects, and in 84 per cent the period of isometric relaxation was determined. The authors compared several pulsating structures from the chronometric standpoint. The third work referred to 110 electrokymographic studies, in each of which twenty to thirty different points of the heart contour were studied. The four heart chambers, the great vessels, the pulmonary circuit, and so forth were also investigated. Several pathologic cases were examined, among which were syphilitic aortitis, rhythmic disturbances, constrictive pericarditis, rheumatic valvular diseases, and so forth. The data were compared with the electrocardiographic, radiologic, and laboratory data. The authors concluded that the method had been useful in the diagnosis of mediastinal tumors, patency of the ductus, interauricular septal defects, different valvular diseases, and myocardial infarction.

2. Finally, a study on the clinical value of the electrokymogram in myocardial infarction was presented.[50] The authors analyzed the curves in different locations of myocardial infarctions, and they discussed the deformations of the tracings considered as characteristic. An opinion on the pathogenesis of these deformations was given.

3. A new method of radiologic investigation was presented, regmography.[51] This consists of the impression on radiographic plates through a narrow slit during the "semi-periods" of the alternating current on which the x-ray machine operates. The method allows the taking of 100 impressions per second, for which reason the author claims it is superior to movie-roentgenography. The author has made studies using opaque substances in experimental animals and intends to prove the great value of the method in studying physiologic and physiopathologic hemodynamics.

4. A device called cardiometric quadrant[52] was presented. It gives the different cardiac diameters and the cardiac angle through a graduated scale placed in front of the fluoroscopic screen.

5. Tomography was the subject of two papers. One referred to the differential diagnosis of mediastinal tumors and other pathologic processes.[53] The value of the method was stressed emphatically. The results were analyzed in cases of aneurysm of the pulmonary artery and its branches and the differential diagnosis with aneurysm of the descending aorta, with aneurysm of the posterior and superior aspects of the left ventricle, and with mediastinal tumors. This paper also included a study of the anatomy of the normal mediastinum from the radiotomographic standpoint with special reference to the vessels contained therein.

6. The second work on tomography dealt with cardiovascular pathology[54] (with the exception of mediastinal tumors and aneurysms of the basal vessels). In this paper two cases of juxtacardiac tumors were presented. Cardiac hypertrophy and dilatation were studied in an attempt to dissociate the two ventricular portions. Mitral stenosis was studied, and the shadow of the left auricle was "dissociated," thus giving rise to a new sign, that of the "superelevation of the left branch of the pulmonary artery." Other valvular diseases were studied, and several cases of congenital heart disease were reviewed: Fallot's tetrad, interauricular septal defect, patency of the ductus, coarctation of the aorta, and so forth. The authors stated that in cases of patency of the ductus they can visualize the ductus itself.

7. As regards angiocardiographic studies, the following were reported. Angiocardiography in the diagnosis of interauricular septal defect[55] gave a correct diagnosis in 93.4 per cent of the cases confirmed by autopsy or by catheterization (a total of fifteen cases). The authors thought that the success of their diagnosis was due to the use of an opaque substance injected directly into the heart or through a jugular vein into the right auricle or the right ventricle. A summary of the radiologic signs is given: simultaneous filling of all the heart chambers at the end of the injection, early filling of the left auricle simultaneously with the right cavities, refilling of the right auricle during the filling of the left cavities, and, finally, late filling of the right auricle at the same time as the left cavities if the opaque substance is injected directly into the right ventricle. They stated that it is impossible with this method to judge the size of the septal defect or the degree of the blood shunt. The method does give true information as to the size of the right heart chambers and the condition of the pulmonary artery

and of the aorta, but the presence of a septal defect may introduce an error in the estimation of the size of the pulmonary conus and the caliber of the pulmonary artery.

8. Another paper dealt with the diagnosis of the patency of the ductus in sixteen patients,[56] proved by catheterization, by surgical correction, or by autopsy. This study showed (a) that the most frequent angiocardiographic signs are the persistence of the filling of the pulmonary artery, especially its left branch, and the refilling of the pulmonary artery during the filling of the aorta, both of which signs were present in 85 per cent of the angiocardiograms; (b) that good results are due to the intracavity injection method; and (c) that in a patient with great pulmonary hypertension, the opaque substance took a reverse course from the pulmonary artery to the aorta.

9. There was a paper dealing with the analysis of 200 angiocardiograms[57] and their comparative values according to the path used for the injection of the opaque substance. A study of the clinical, catheterization, operative, and necropsy findings was also reported. It was indicated that the best method is that by which the opaque substance is injected directly into the heart chambers, be it the auricle or the ventricle. By this method 75 per cent of the angiocardiograms are good.

10. There was a paper on the angiocardiographic method used for the study of the collapse of the venous vessels in the thorax in normal individuals.[58] The authors stated that a collapsed vein projects an irregular and reduced shadow. Their plates showed that the position of the body was the cause of this collapse, juxtathoracic for the subclavian and jugular veins in the recumbent or sitting positions. The inferior vena cava was collapsed in the erect position. There was a collapse of the inferior vena cava at the level of the diaphragm, and the opaque substances could not pass from the right auricle to the inferior vena cava. In congestive heart failure, on the contrary, opaque substances may easily pass from the right auricle to the inferior vena cava and the suprahepatic veins. The superior vena cava was distended in the upright position, and the subclavian and jugular veins were also distended instead of being collapsed.

11. A study of 15,000 chest plates (after the technique of Abreu)[59] was presented from which those suspected of showing heart or vascular disease were selected. The method proved valuable for correct diagnosis in 80 per cent of the cases when compared with more accurate methods of examination, so that it is highly recommended for the research of cardiovascular disorders in supposedly normal individuals.

12. In disorders of the portal venous circulation a phlebographic method was described[60] in an attempt to clarify clinical syndromes of difficult interpretation. With this method it was possible to determine the extension and location of the thrombosis or spasms of the tributary veins and the main venous vessel of the portal system.

13. A paper was read dealing with a method for the reconstruction of the cardiac silhouette by direct calculation from the fluoroscopic examination.[61] The method is based on physical and geometric principles and is supposed to be a

good substitute for orthodiagraphy due to its simplicity and quickness. A table for normal standards was given in this study.

14. A radiologic study of the various images of chronic cor pulmonale was undertaken.[62] The author pointed out the different shapes of the heart and its vessels and insisted on the always present contrast between the large and dense hilar shadows and the clearness of the lung fields. He also insisted on the fact that the middle arch is not easily delineated, that the diaphragmatic surface of the right ventricle is large, and that the interventricular notch is greatly displaced.

15. A paper was read on tricuspid lesions and their diagnosis. It referred to a new sign, the visualization of the azygos vein,[63] in seventy-five tricuspid lesions (stenotic and regurgitation), an elongated shadow, placed immediately external, yet close to the clarity of the right bronchus. This was possibly due to the stasis in the superior vena cava and its displacement caused by the dislocation of the left bronchus through an enlarged left auricle. This was supposed to be so since all tricuspid lesions were considered secondary to mitral stenosis.

16. Angiocardiography in tetralogy of Fallot[64] was the subject of a paper in which the great value of the method was emphasized in contrast with the few clinical signs. This was considered especially noteworthy since a biventricular aorta can be visualized and since data of great value for the surgeon can be thus secured, such as the approximate thickness of the branches of the pulmonary artery and the subclavian and carotid arteries and their situation. It also affords important facts for the differential diagnosis with other congenital heart abnormalities such as transposition of the great vessels, tricuspid atresia, and so forth.

17. There was another paper presenting clinical, angiocardiographic, and comparative anatomy data on cases of isthmic stenosis of the aorta.[65] The authors reviewed the problem from the point of view of comparative anatomy, using angiocardiography and dissection of different animal species. They found in reptiles (chelonides) a similar, although not identical, anatomic structure to that of human aortic stenosis. This led them to conclude that this abnormality was not a philogenic malformation. They also concluded that angiocardiography is not a valuable method for the diagnosis of coarctation of the aorta, but it is valuable for the surgeon because it affords him accurate facts on the situation, morphology, and extension of the constricted zone.

18. A study of the patency of the ductus was undertaken from the hemodynamic, electrocardiographic, and clinical aspects[66] with special reference to electrocardiography. Twenty-one cases were analyzed, and the authors found that this malformation tended to elevate the T waves in the leads that register left ventricular potential. In cases complicated with pulmonary hypertension both $\hat{A}QRS$ and $\hat{G}$ were deviated to the right, and the R in V_1 was elevated. In a great number of cases the aspect of V_1 allows the distinction between patients with interauricular septal defect and those with patency of the ductus complicated by pulmonary hypertension.

19. Several studies were presented that dealt with subacute bacterial endocarditis, one of which covered its experimental production.[67] Strains of *Streptococcus viridans* were injected into a group of 107 rabbits, and lesions were obtained exactly resembling those of the human bacterial endocarditis in 48 per cent of the cases. This study proved (a) that the number of bacteria injected directly influenced the incidence of endocardial lesions in 50 per cent of the cases, as compared with cases where smaller numbers were used; (b) that endocardial localizations were more frequent in those animals in whom the endocardium was previously traumatized; (c) that the animals showed other signs typical of the disease as seen in the human race, especially thromboembolic phenomena in different organs; and (d) that penicillin-treated animals were less subject to these thromboembolic complications.

20. A comparative study between rheumatism and subacute bacterial endocarditis as concerns blood cultures was presented.[68] This was done in normal subjects, in rheumatic individuals, and in some suffering from subacute bacterial endocarditis. Results were negative in the first group, positive in 1.14 per cent of the rheumatic subjects, and positive also in 57.69 per cent of the last group. The authors insisted on the fact that the larger the number of cultures made on the same subject the greater the possibility of obtaining positive blood cultures in cases of subacute bacterial endocarditis. As far as the relation between the presence of positive blood cultures in subacute bacterial endocarditis and the presence of fever, they found a greater incidence of positive blood cultures when the temperature was higher. The bacteria found in this study were mainly *Str. viridans* (forty-four cases among forty-five positive culture germs), and there was but one case of brucella. The authors summarized briefly the behavior of the cultured bacteria toward penicillin, streptomycin, and aureomycin. The majority of the strains were sensitive to therapeutic doses of penicillin.

21. Subacute bacterial endocarditis was studied clinically, especially in regard to the temperature curve.[69] Six hundred autopsies were investigated, and thirty confirmed cases of subacute bacterial endocarditis were found. Among other purposes the study referred especially to those patients who showed a normal and protracted temperature curve, which was the cause for delayed diagnosis. The authors attributed this finding to the widespread use of antibiotics. They analyzed some clinical and etiologic factors, and they stated that they have never observed cases of subacute bacterial endocarditis in rheumatic individuals under 12 years of age.

22. Studies on abacterial endocarditis were presented.[70] These patients did not give positive blood cultures, not because there were no circulating bacteria, but because even cultures taken with aseptic precautions from the valves of the hearts of these patients were sterile. At any rate, the authors claimed to have obtained a culture (from the bone marrow) of a new organism which they called *Corynebacterium endocarditis*.

23. Another paper dealt with the differential characteristics between subacute bacterial endocarditis and subacute abacterial endocarditis.[71] These differences of clinical, bacteriologic, and therapeutic nature were discussed, and it was stated that the nonbacterial type has a systematically negative blood

culture with a low sensitivity to penicillin. It is prominent in the male sex, has peculiar clinical manifestations, and frequently exhibits malnutritional features.

24. A study of the classification of the clinical forms of cardiac localization in rheumatic fever[72] was presented. Its author divided rheumatic processes of the heart into two groups, active and inactive. The former was subdivided into acute (which may be benign, severe, or malignant) and chronic. The latter group is the valvular sequel of rheumatism. The purpose of this classification is to "isolate types and standardize concepts."

25. There was a paper on mitral stenosis in old age.[73] One hundred and five patients over 50 years of age were studied. Various etiologic factors were analyzed in this paper as well as the early symptoms of the ailment and its evolution, the electrocardiographic signs, and the complications observed.

26. A study of aortic stenosis was presented[74] wherein the difficulty for diagnosis was stressed. Seven hundred and fifty autopsy cases were reviewed and fifty-four were chosen for the analysis of the etiology. The value of clinical symptoms and radiologic signs for the diagnosis of this disease was analyzed.

PAPERS SUMMARIZED

1. Chávez, I., Cuellar P., A., and Cesarman, T.: Infartos del pulmón y cor pulmonale agudo (Estudio de 200 casos con confirmación microscópica), Inst. Nac. de Card. México.
2. Méndez, L., Zajarías, S., and Sáenz Arroyo, L.: Lesiones vasculares encefálicas encontradas en 750 autopsias del Instituto de Cardiología de México, Inst. Nac. de Card. México.
3. Costero, I.: Contribución al estudio de las reacciones de la microglia del sistema nervioso central en los enfermos atacados de reumatismo agudo, Inst. Nac. de Card. México.
4. Costero, I., and Barroso Moguel, R.: Sobre las alteraciones vasculares de las válvulas del corazón observadas en el curso de la endocarditis reumatismal, Inst. Nac. de Card. México.
5. Piaggio Blanco, R., Dubourdieu, J. J., Dighiero, J., Canabal, J. E., and Grosso, O.: Quiste hidatídico de la aurícula derecha, equinococosis pulmonar metastática y corazón pulmonar crónico hidatídico causado por una obstrucción parasitaria de la arteria pulmonar izquierda y de sus ramas, Uruguay.
6. Rivero Carvallo, J. M.: Semiología de la insuficiencia y de la estenosis tricuspídea, Inst. Nac. de Card. México.
7. Etchevés, J. C., Cozza, A. A., and Becker, L.: Secuelas cardíacas de la fiebre de malta, Argentina.
8. Perrín Chico, M.: Cardiopatía de la enfermedad de Chagas experimental, Inst. Nac. de Card. México.
9. Laranja, F. S., Dias, E., and Pellegrino, N: Cardiopatía chagásica como identidad cardiológica, Brasil.
10. Villela, E. de A.: Descripción clínica de la enfermedad de Chagas, Brasil.
11. Manrique Izquieta, J.: Cardiopatía chagásica crónica, Ecuador.
12. Maldonado Allende, I.: La brucelosis cardiovascular; Contribución a su estudio, Argentina.
13. Burlamaqui Benchimol, A., and Schlesinger, P.: Cardiopatía beribérica, Brasil.
14. Gómez González, C. F., and Cue Méndez, P. A.: Requisitos de temperatura y de humedad atmosféricas en relación con las enfermedades vasculares "constante vital de temperatura y humedad atmosféricas," Cuba.
15. Peralta, V. A., Castaneda, P. L., and Robles, R. G.: Infartos miocárdicos post-transfusionales, Perú.
16. Cuoco, J., and Ibalbi, J. C.: Insuficiencia cardíaca por esclerodermia, Uruguay.
17. Porto, J.: Silicosis y "cor pulmonale" crónico, Portugal.
18. Taquini, A. C., Suarez, J. R., González Fernández, J. M., and Berdaguer Arriaga, J.: Cor pulmonale subagudo broncógeno, Argentina.
19. Maldonado Allende, I., Aznarez, E., Camponovo, P. B., and Mariana, A.: Bases para el diagnóstico de los cardíacos negros de Ayerza, Argentina.

20. Estapé, F. A.: Pseudo enfermedad de Hutinel-Pick con hígado y bazo ensanchados (estudio clínico, electrocardiográfico y anatomopatológico), España.
21. Vega Diaz.: Mecanismo cardiovascular de los síncopes desencadenados por la tos (síncopes tusígenos), España.
22. Dos Santos, J. C.: Sobre la "periflebitis edematosa" desarrollada con aumento de trombosis venosas agudas y la "periflebitis estenosante" que puede seguirlas, Portugal.
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24. Mazzei, E. S., Schaposnik, F., Reca, R. R., and Grinfel, D.: Trombosis crónica aorto-ilíaca (síndrome de Lériche), Argentina.
25. Jiménez Diaz, C., Barrera, P., and Molina, A. F.: La secreción interna de la pared arterial y su intervención en la regulación de la presión arterial, España.
26. Taquini, A. C., and Fasciolo, J. C.: Contenido de renina en el riñón normal y en diversas condiciones experimentales, Argentina.
27. Braun-Menendez, E.: Metabolismo del agua y de los electrolitos e hipertensión arterial experimental, Argentina.
28. Camponovo, P. B., and Masello, J.: Acción de la vitamina K sobre la hipertensión arterial y la colinesterasa sérica, Argentina.
29. Berconsky, I., Fajelbaum, D., and Nijensohn, A.: Fragilidad capilar en la hipertensión arterial; Su valoración por los métodos de presión positiva y negativa, Argentina.
30. Méndez, L., and Chávez, I.: El tratamiento simpaticolítico de la hipertensión arterial esencial, Inst. Nac. de Card. México.
31. Kuntz Busch, R.: Tensión arterial normal según el biotipo, el sexo y la edad, Brasil.
32. Borges, S., and Novelo, S.: La persistencia del canal arterial desde el punto de vista hemodinámico, electrocardiográfico y clínico; El diagnóstico clínico de los casos atípicos, Inst. Nac. de Card. México.
33. Novelo, S., Limón, R., and Bouchard, F.: Un nuevo síndrome con cianosis congénita: La persistencia del canal arterial con hipertensión pulmonar, Inst. Nac. de Card. México.
34. Bouchard, F., Limón Lason, R., and Rubio Alvarez, V.: Ocho casos de persistencia del canal arterial con gran hipertensión pulmonar, cuatro de ellos con cianosis, Inst. Nac. de Card. México.
35. Rubio Alvarez, V., Limón Lason, R., and Bouchard, F.: Diagnóstico de la persistencia del canal arterial por medio del cateterismo de la aorta a través del canal; Presentación de 25 casos, Inst. Nac. de Card. México.
36. Mispireta Dibarbout, A., Cornejo Zavala, G., Mayta Balazar, F., and Figari, R.: Valor diagnóstico de la angiocardiografía en las cardiopatís congénitas, Perú.
37. Alzamora-Freundt, R., Peralta, A., Mispireta, A. D., Delgado, R., Moyano, P., Roitman, M., Reyna, R., and Chávez, R.: El valor de la cateterización intracardiaca en el diagnóstico de los defectos septales y de la persistencia del conducto arterial, Perú.
38. Novelo, S., and Cahen, P.: Consideraciones sobre el diagnóstico clínico de diferentes variedades hemodinámicas de la comunicación interauricular, Inst. Nac. de Card. México.
39. Borges, S., and Novelo, S.: La tetralogía de Fallot con dilatación postestenótica de la pulmonar; Consideraciones diagnósticas, Inst. Nac. de Card. México.
40. Rubio Alvarez, V., Limón Lason, R., Bouchard, F., and Novelo, S.: Estudio de las venas pulmonares; Su presión y su saturación de oxihemoglobina, Inst. Nac. de Card. México.
41. Limón Lason, R., Rubio Alvarez, V., and Bouchard, F.: Estudio de las curvas de presión de las cavidades izquierdas y del ciclo cardíaco en el hombre, Inst. Nac. de Card. México.
42. Moia, B., Baudino, C., and Malinow, M. R.: Estudios segmentarios de la presión venosa en el hombre mediante el cateterismo cardíaco, Argentina.
43. Duomarco, J., and Rimini, R.: La presión venosa en las extremidades, Uruguay.
44. Ramos López, M., and Castanheira, A.: Hemodinámica y estenosis mitral, Portugal.
45. Limón Lason, R., Rubio Alvarez, V., and Bouchard, F.: La estenosis aórtica clínica sin signos hemodinámicos apreciables por el cateterismo de las cavidades izquierdas, Inst. Nac. de Card. México.
46. Carvalho, L., Sousa, A., and Vidal, C.: Estudio quimográfico de la circulación pulmonar, Portugal.
47. Dussaillant, G., Alessandri, H., Lepe, A., and Gómez, G.: Amplitud y forma del electrokimograma ventricular izquierdo normal, Chile.
48. Dussaillant, G., Alessandri, H., Lepe, A., and González, J.: Estudio electrokimográfico de la cronometría ventricular izquierda, aórtica y pulmonar, Chile.

49. Alessandri, H., Dussaillant, G., and Lepe, A.: Experiencia clínica en electrokimografía, Chile.
50. Madeira-Pinto, P., and Saldanha, A.: Valor clínico de la electrokimografía en el estudio de los infartos del miocardio, Portugal.
51. Sousa, A.: Regmografía en los estudios experimentales de hemodinámica, Portugal.
52. Barletta, F.: Cuadrante cardiométrico, Inst. Cardiológico Córdoba, Argentina.
53. Rabina, P., Simón, P., and Aguirre, F.: La tomografía en los procesos vasculares del mediastino; Diferenciación con otros procesos patológicos de la misma región, Cuba.
54. Govea, J., and Aguirre, F.: La tomografía en patología cardiovascular, Cuba.
55. Puigbó, J. J., Moura Campos, C., Dorbecker, N., and Cahen, P.: La angiocardiografía en el diagnóstico de la comunicación interauricular; Valor del método por sonda intracardíaca, Inst. Nac. de Card. México.
56. Moura Campos, C., Dorbecker, N., Cahen, P., and Puigbó, J. J.: La angiocardiografía en el diagnóstico de la persistencia del canal arterial; Valor del método por sonda intracardíaca, Inst. Nac. de Card. México.
57. Cahen, P., Moura Campos, C., and Puigbó, J. J.: Estudio comparativo de los angiocardiogramas según la vía de introducción de la substancia opaca, Inst. Nac. de Card. México.
58. Duomarco, J., Rimini, R., and Sapriza, J. P.: El fenómeno del colapso en los troncos venosos del tórax, Uruguay.
59. Rojas, R. A.: Abreugrafía de corazón y grandes vasos en supuestos sanos, Argentina.
60. Pereira, A. de S.: El método flebográfico en el estudio de los trastornos de la circulación del sistema porta, Portugal.
61. Barletta, F., Bustamante, L. F., and Vieyra Sánchez, E.: La reconstrucción de la silueta cardiovascular sobre la calca directa obtenida al examen radioscópico, Argentina.
62. Codina Altés, J.: Las imágenes cardiovasculares del cor pulmonale, España.
63. Azpitarte, A.: La visibilidad de la vena azigos con signo radiológico de las lesiones tricuspídeas, España.
64. Dorbecker, N., Ceballos, J., Moura Campos, C., and Puigbó, J. J.: Tetralogía de Fallot; Estudio angiocardiográfico, Inst. Nac. de Card. México.
65. Dorbecker, N., Chávez, I., and de la Cruz, M. V.: Estenosis del istmo de la aorta; Hechos clínicos, angiocardiográficos y de anatomía comparada, Inst. Nac. de Card. México.
66. Cabrera, E., Borges, S., and Novelo, S.: La persistencia del canal arterial desde el punto de vista hemodinámico, angiocardiográfico y clínico; Estudio electrocardiográfico, Inst. Nac. de Card. México.
67. Paula Nogueira, H.: Endocarditis lenta experimental, Portugal.
68. Salazar Mallén, M., and Bronstein, L.: El hemocultivo en la fiebre reumática y en la endocarditis bacteriana, Inst. Nac. de Card. México.
69. Aceves, S., and Cesarman, T.: Estudio clínico de algunos aspectos de la endocarditis bacteriana (particularmente de la curva térmica), Inst. Nac. de Card. México.
70. Jiménez Díaz, C., and Arcona, E.: Ulteriores consideraciones sobre las endocarditis abacteriana, España.
71. Trias de Bes, L., Foz Tena, A., Gras Riera, J., and Ballesta, F.: Estudio crítico de los caracteres diferenciales entre las endocarditis lentas bacterémicas y no bacterémicas, España.
72. Herrera, Ramos F.: Estudio y clasificación de las formas clínicas de las localizaciones cardíacas de la fiebre reumática, Uruguay.
73. Vela, M., and Benot, E.: La estrechez mitral en edad avanzada, España.
74. Vaquero, M., and Cesarman, T.: La estenosis aórtica; incidencia y diagnóstico, Inst. Nac. de Card. México.

Book Review

Morbus Caeruleus. An Analysis of 114 Cases of Congenital Heart Disease With Cyanosis. By S. Eek, M.L., W. Graf, M.L., C. G. Herdenstam, M.K., H. Lagerlöf, M.D., Y. Larsson, M.L., A. Lichtenstein, M.D., E. Mannheimer, M.D., T. Möller, M.L., Ph. Sandblom, M.D., M.S., F. Ulfsparre, M.L., and L. Werko, M.D. Edited by E. Mannheimer. Basel and New York, 1949, S. Karger, 332 pages. Price $9.25.

This monograph is an analysis of 114 cases of congenital heart disease with cyanosis by a group of distinguished cardiologists at the Crown Princess Lovisa's Children's Hospital in Stockholm. The patients were studied by detailed history and physical examination, fluoroscopy, electrocardiography, phonocardiography, and, in many instances, angiocardiography and cardiac catheterization. These and many other aspects of congenital heart disease are described in detail and represent the first attempt to bring together the anatomical, physiological, and clinical aspects of the various types of cyanotic congenital heart disease. The need for doing so is apparent, and the authors point the way to its accomplishment. There is a generous bibliography. This monograph is recommended to the student of congenital heart disease for reference rather than as a textbook, and in it will be found much valuable information.

L. D.

Erratum

On page 837 of the December, 1950, issue in the article "Electrocardiographic Changes in Pulmonary Embolism With Special Reference to an Early and Transient Shift of the Electrical Axis of the Heart" by P. T. Kuo and Joseph B. Vander Veer, the next to the last line should read: "one may observe prominent S waves in Lead aV_L. . . ."